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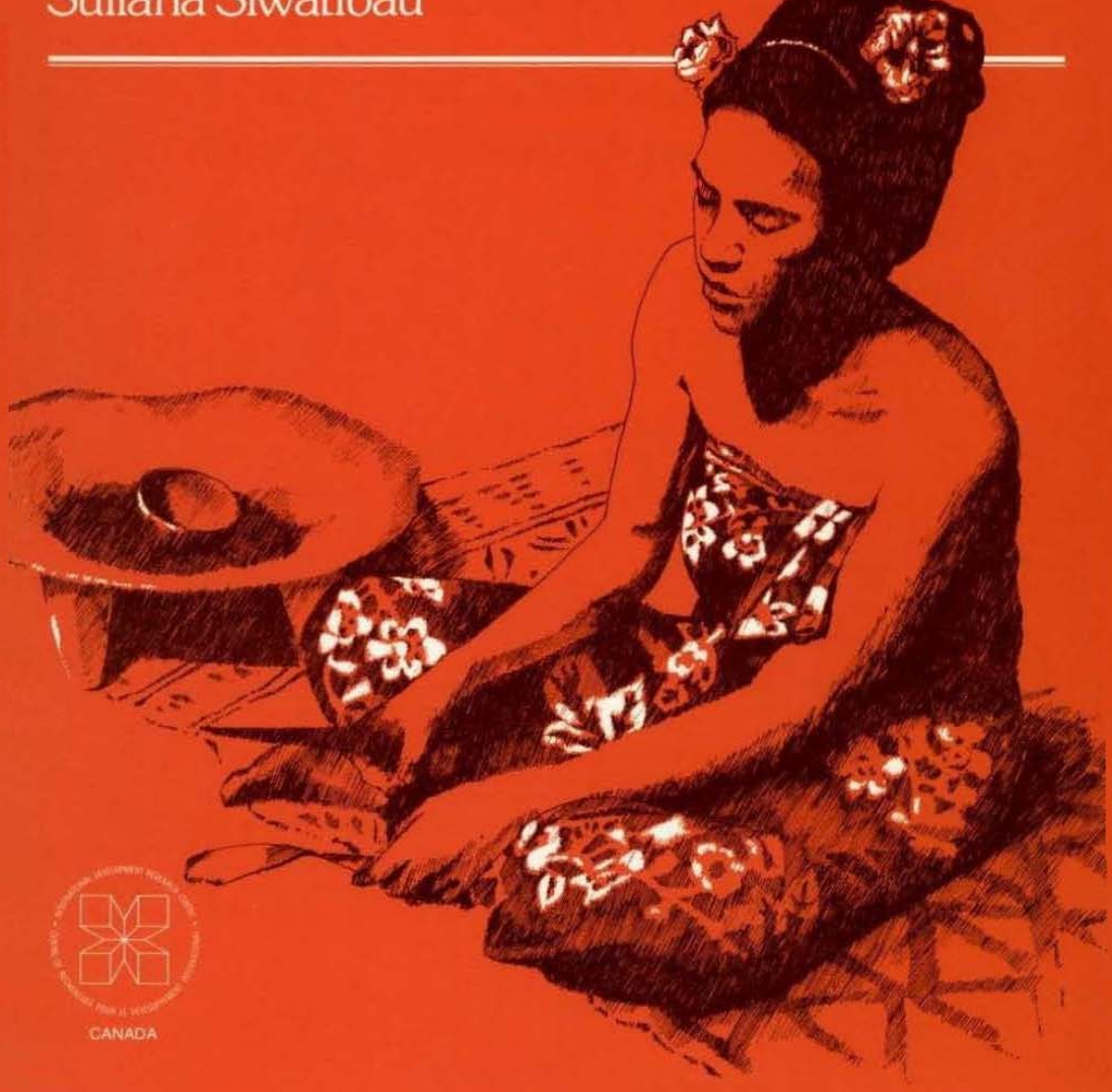
Rural Energy in Fiji: a survey of domestic rural energy use and potential

Suliana Siwatibau



CANADA

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Postal Address: Box 8500, Ottawa, Canada K1G 3H9
Head Office: 60 Queen Street, Ottawa

Siwatibau, S.

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A Survey of Domestic Rural Energy Use and Potential

Suliana Siwatibau

A report to the Fiji Government with financial assistance from the International Development Research Centre. The views expressed in this publication are those of the author and do not necessarily represent the views of IDRC.

Contents

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This project was made possible by a generous grant from the International Development Research Centre (IDRC), with supporting grants from the Fiji Government and the University of the South Pacific's Centre for Applied Studies in Development (CASD). Originally, the work was planned to cover ten months of field data collection with one month for a literature survey and one month of report writing. However, there was a cost and time overrun and I am particularly grateful to CASD for covering my salary over an extra three months and to the General Planning Office (Fiji Government) and the Hans Seidel Foundation of Munich for meeting the costs of printing the first draft of this report and other overhead costs.

This project was managed by the CASD and was executed by the following CASD staff: S. Siwatibau, Principal Researcher and Project Leader and L. Vaganalau and P. Chand Lal, Research Assistants. The CASD is indebted to the University's natural scientists, the Director of the Fiji Government's Central Planning Office and his staff, and the following members of the Advisory Committee who gave of their valuable time to make invaluable comment and give advice: D. Medford, Chairman, CASD; J. Cavalevu, Permanent Secretary, Ministry of Fijian Affairs and Rural Development; P. Johnston and M. Sturton, Central Planning Office, Fiji Government; J. Atkinson, Fiji Institute of Technology; and B. Ponter, University of the South Pacific.

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I acknowledge the willing contribution and cooperation to field work of senior students of the University, village elders, farmers, and government officials who helped in so many ways. Those who gave notable and repeated contributions to field work are listed in Appendix 1.

The difficult task of typing the manuscript fell to the lot of the overworked Secretary of CASD, Mrs Seru Ravonu, to whom I am most grateful.

Suliana Siwatibau

Summary

The project's aims were to survey current energy use and needs in selected rural areas of Fiji and to evaluate alternative sources of energy supply. In particular, an assessment was to be made of the advisability of expanding the use of biogas and the possibility of improving conditions of domestic cooking, notably through conservation.

The project used a variety of secondary sources to supplement primary data obtained in field surveys carried out from a sample of the 115 households in four representative villages and seven isolated homesteads. A brief survey of a periurban area near Suva was also made for comparison.

A summary of our main observations and conclusions leading to specific recommendations follows:

(1) Fuelwood Consumption

Observation

Of the homes surveyed, 92% cook with wood over an open fireplace. Of the mean 506 kg (oven-dry weight) of wood consumed annually by a rural person, 353 kg is consumed by home cooking and food preservation. Measurements of fuelwood stands available to our case study populations reveal that these can sustain at least 5–13 times the present rate of consumption; however, agricultural clearing will diminish fuelwood foraging. Assuming a minimum 5-year fallow period before reuse of land for shifting cultivation, a 15-year regeneration period for secondary bush trees, and a 2.5% annual rate of population increase in Fijian villages, expected periods of attaining a critical level of demand on the land vary from 4.3 to 72.6 years for our case study villages.

Conclusion

Most rural peoples will continue to use wood for cooking because it has no financial cost and is readily available. In a few areas, however, supplies will become critical within the next 10 years.

Recommendation

- That government identify suitable, fast-growing fuelwood species, such as *Leucaena leucocephala* or *Gliricidia sepia*, and consider means of incorporating fuelwood cultivation within existing agricultural systems where pressure on the land is becoming critical.

(2) Stove Design

Observation

Cooking over an open fire is inefficient. Tests showed that open fire cooking is only 5–10% efficient; it is also unhealthy. Although direct medical

evidence is not available, greater frequency of chest complaints in Fijian populations may be influenced by sleeping in, and sustained exposure to, a smoky atmosphere. The proportion of women interviewed who complained of eye irritation by smoke ranges from 33% to 91% in our various case study settlements.

Conclusion

There is a need for a cheap, clean, wood-burning stove for rural cooking. Of all women interviewed, 83.3% desire better cooking facilities.

Recommendations

- That the ongoing development of a cheap, clean, wood-burning stove by the Fiji Forestry Department and the University of the South Pacific should continue to be supported and monitored. Greater involvement of women's organizations and rural women should be solicited before final specifications are made.

- That whatever stove design finally evolves should be made available in at least three forms to cater to different income levels in rural situations. These three forms need to be: (1) a completed stove ready for installation in institutions, such as schools, and better-off homes; (2) completed stove parts that can be readily assembled in the home — for those of more limited means; and (3) molds of parts that can be made available to villages and rural homes for those who prefer to make their own stoves. Molds must be made available in sufficient quantities and clear instruction sheets in all three major languages should be provided with them.

(3) Home Heating

Observation

Temperatures at interior villages of Viti Levu fall sufficiently low to justify log fires in Fijian "bures" (homes) for periods ranging from 1 to 6 months but averaging 5 months every year. Those homes with corrugated iron roofs are not warmed because of copious condensation on the iron roof interior surface. Wood used for warming homes was not monitored because a second visit during the cold season had to be canceled.

Conclusion

Of interior rural peoples interviewed, 100% would welcome some means of keeping their homes warm without having to sleep in smoky, thatched bures.

Recommendation

- That while government develops model rural homes, the special case of interior rural peoples should be taken into account. Discussions between the Public Works Department architects and the Forestry Department utilization officers should lead to a solution. Additions or modifications to the Forestry Department's wood stove may be a possibility.

(4) Kerosene Cookers

Observation

An increase in annual cash income of rural households is usually accompanied by the acquisition of kerosene cookers. For example, we found kerosene cookers present in 2% of homes with less than $200 annual gross cash income, 50% of homes with $600–$800 annual gross cash income, and 100% of homes with $1400–$1600 annual gross cash income.[1] In addition, as annual cash income increases, according to our survey population, consumption of kerosene for cooking increases. Our elasticity tests showed that a 1% increase in annual family gross cash income results in a 1.5% increase in kerosene consumption.

The most commonly used kerosene cooker, as revealed by a Fiji Consumer Council survey, is the Hong Kong round wick single burner. This is the cheapest cooker available in Fiji. Our tests on a selection of low-cost cookers showed the Hong Kong cooker to be 15–29% efficient and the common Swedish primus to be 30–57% efficient.

Tests conducted by the New Zealand Consumer Council for efficiency and fire hazard showed that of the 13 types of kerosene cookers available in Fiji in 1976 the five cheapest should neither be used nor recommended, and the four most expensive presented moderate fire danger. Only four in the middle-price range performed satisfactorily in the tests.

Conclusion

People will continue to buy the less efficient kerosene cookers, which present the greatest fire hazard, because they are the cheapest available. Consumers are generally unaware of the safety and efficiency features of the cookers on the market.

Recommendations

- That government examine the New Zealand Consumer Council tests and act on their recommendations as necessary. Our tests indicate that the less efficient Hong Kong cooker needs improvement in design not only to increase efficiency in fuel use but also to raise safety standards.

- That government stipulate a set of minimum requirements for safety and efficiency to ensure that cookers on the market conserve fuel and are safe for consumers. A Standards Board should be set up to inspect and evaluate the cookers that are presently available and any that may be introduced to the market in the future.

(5) Lighting

Observation

Of the households surveyed, 74% use kerosene and benzine lamps. Of these, 43% use kerosene lamps only. The most widespread lamp (40% of all lamps used) is the hurricane kerosene lamp, which emits only a mean 3 footcandle light intensity at 30 cm distance. It is also the cheapest lamp (0.23¢/h of lighting). Better lighting in some homes is achieved through the benzine coleman pressure lamp (11% of total lamps). This lamp, when well pumped, emits light of a mean 25 footcandle at 30 cm. Benzine is however highly flammable and expensive (1.74¢/h of lighting). The kerosene tilley lamp is

[1] The Fijian dollar is tied to a daily average of the Japanese yen, U.S. dollar, British sterling, New Zealand dollar, and Australian dollar. All financial costs are in Fijian dollars. The exchange value for the Fijian dollar on 12 December 1978 was Fiji $1.00 = U.S. $1.885.

much less common (1% of all lamps) but is as bright as, if not brighter than, the benzine lamp (mean 32 footcandle at 30 cm distance). Kerosene is less flammable than benzine and cheaper (0.92¢/h of lighting).

The government's scheme for rural electric lighting by small auto-generators does provide improved lighting conditions; however, in most cases it is more expensive for the consumer when compared to tilley or benzine lamps. Our economic analysis shows that of all generators installed so far, or ready to be installed, 94% are not going to be economically viable. The heavy government subsidy (five-sixths) will enable the villages installed with output of at least 15 kW to recover capital costs. Only the large systems of 30 kW and more (7% so far) produce lighting at less cost than the benzine lamp. However, because running costs are also subsidized to the villagers, only those villages with 10 kW systems or less (48% so far) produce lighting at a greater cost than the benzine gas lamp.

Conclusion

For better lighting, diesel electric generation is going to be a further drain on the meagre cash supply in most villages. If electricity generation is not concurrently utilized for productive activities, kerosene tilley lamps will be of greater benefit to most rural people.

Recommendation

- That local construction or importation of more kerosene tilley lamps be encouraged by introducing appropriate fiscal measures and the lamps be sold at subsidized rates to bring inexpensive, reliable lighting to more rural peoples as soon as possible.

(6) Hot-Water Systems

Observation

The majority of people interviewed (91.3%) wished to have hot water readily available at their homes for cooking, washing, bathing, and steam baths. They were all willing to make cash contributions toward either community or individual systems.

Conclusion

Some means of providing readily available hot water for rural homes is desirable.

Recommendation

- That government support and encourage investigations into developing simple and inexpensive means of providing readily available hot water to rural communities. A hot-water system attached to a wood-burning stove should be sufficient for most needs. Where larger quantities are required (such as for community use) solar hot-water systems should be examined.

(7) Biogas Digesters

Observation

Of the 16 known biogas digesters in Fiji, 15 are fed pig waste and one is fed poultry waste. Our economic analysis of pig waste-fed digesters shows that at present levels of use, all but one (7.5 m^3) show disappointing economic returns. This is largely due to underloading and underutilization.

The burden of heavy initial capital costs can be alleviated through a government subsidy. We observed that when materials were obtained through government supplies, the costs were equivalent to a 27% subsidy. We noted that a 25% subsidy improved economic returns markedly. Our analysis also showed that returns on all the different digesters presently working in Fiji would be satisfactory if the digesters were utilized at optimum levels. The smallest economically viable concrete and steel-top digester can be fitted to a 30-animal piggery to supply cooking fuel for a family of six. We also noted that small concrete digesters are expensive and the use of less expensive materials, such as neoprene, would improve the benefit/cost ratio.

It was evident that the Agriculture Department, which is presently responsible for building, servicing, and monitoring biogas digesters, has neither sufficient manpower nor other resources to either promote or monitor satisfactorily the continued extension of biogas systems in Fiji.

Conclusion

The installation of digesters in commercial piggeries of 30 pigs or more is worthwhile, provided the digesters are utilized at optimum level.

Because of the high initial capital costs, any digesters built with existing designs and materials and installed at farms that do not have pigs should be located only in commercial animal farms such as at poultry and dairy sheds. Present designs are not yet suitable for village use.

It is necessary to have a special body, unit, or institution responsible for biogas systems, not only for construction but also for information dissemination, monitoring progress, servicing, and technology development.

Recommendations

- That farmers using existing digesters be informed of the results of our analysis and be encouraged to use their digesters fully. Government can help by making appliances, such as gas lights, more readily available to the farmers. Simple information sheets on use, advantages, and maintenance of biogas systems should be provided in all three major languages.
- That any digesters built in future be subsidized. This can be achieved by providing the materials at prices available at the Government Supplies Department.
- That commercial piggeries of at least 30 pigs be encouraged to install digesters for domestic cooking and lighting. Further end uses of biogas may be encouraged in different cases.
- That any digesters built be carefully tailored to animal population, size, and actual end use intended, and be fully tested prototypes.
- That a body or unit within an appropriate government department be given specific responsibility for developing and monitoring biogas systems in Fiji.

(8) Suitable Waste Materials

Observation

Villages regularly produce insufficient organic wastes for biogas generation to satisfy both cooking and lighting needs. The only sizable, regularly produced organic wastes are those from the kitchen, which range from 25.2 kg/day (fresh weight) to 51.5 kg/day (fresh weight) for four villages, and 1.24 kg/day/home (fresh weight) to 2.63 kg/day/home (fresh weight) for isolated farmers.

Animal populations in all the villages and in most of the study case farms are too low for satisfactory biogas production. The highest population of any animal was that of 125 pigs at Nacamaki. Other animals found in villages are cows, chickens, goats, and horses. To utilize animal wastes would involve manual collection of dung from the fields where animals run free-range. Housing them in concrete pens is financially impossible for most rural homes, where the mean annual gross cash income per househould is $544 for villagers and $16 304 for isolated farmers. Concrete pens to house approximately 20 pigs or 6 cows or 40 chickens would cost at least $263.

Our observation of successful and unsuccessful community projects showed that management skills are lacking in villages. Therefore, continuous biogas digesters that require regular daily input and care may be unsuitable for village use. Batch digesters that use mostly vegetable wastes are more promising if technologically possible.

Conclusion

For villages and small farmers without animals biogas possibilities lie in the utilization of vegetable wastes rather than animal wastes.

Recommendation

- That progress of investigations overseas be closely monitored and appropriate biogas technology for villages and small isolated farmers be identified and adopted when opportune. To this end, the successful example of the commercial animal farmers using biogas is important.

(9) Energy, Technology, and Rural Development

Observation

Our social assessment showed a high degree of motivation for better material comforts, significant self-sufficiency, and sufficient enterprise among villagers. Their self-sufficiency, however, is mostly in food supplies, of which a maximum of 22% of daily requirements is obtained through cash expenditure. Isolated farmers, on the other hand, purchase a mean 85% of their daily food requirements.

Conclusion

Significantly, however, aspirations for material comforts can only be satisfied through increased participation in the cash economy. The latter demands an increase in the level of sophistication of rural peoples in the basic skills of commerce. It also demands greater opportunities for cash earning and reliable markets for rural products. As the promotion of rural energy programs and enhanced economic and social activities must go hand-in-hand, the following recommendations submitted by the rural peoples themselves should be accepted as part of the overall rural development program of government.

Recommendations

- That *turaga ni koros*, or village representatives, be taught about and given supervised practice in the use of channels of public service such as how to apply for Fiji Development Bank loans and how to secure a lease.

- That selected people in villages be trained in specific and appropriate skills to run government-aided projects such as plumbing for water supplies, carpentry and welding for copra driers, and simple electrical and mechanical know-how for diesel generation (the cost of such training should be allowed for in all appropriate project proposals).

- That simple instructions in both Hindi and Fijian be provided with all motorized mechanical devices sold so that rural peoples can run them efficiently and carry out simple maintenance requirements as much as possible. Such devices could include outboard motors, motor mowers, land-rovers, small trucks, and tractors.

- That to ensure closer links with rural peoples, top civil servants and parliamentarians should visit rural areas more frequently. (Complaints against civil servants not being in touch were particularly strong.)

- That government facilitate better and more reliable marketing avenues for rural agricultural products. The government's call for increased agricultural production will receive only limited response unless marketing arrangements are improved.

Introduction

Fiji, according to Medford (1977), "has reached a stage of economic growth where future progress and maintenance of present economic output depend critically on imported petroleum products." As a developing country Fiji, with a GDP/capita in current prices of $962 in 1978, will require, for every increment of that growth, a proportionately greater input of energy than is needed to achieve a similar increment in a more developed country. This follows from the contention put forward by Brookes and Medford (see Brookes 1972) that total energy consumption increases logarithmically with a nation's GNP at lower GDP levels. Thus, over the last 2 years, Fiji's economic growth rate in terms of GDP has been estimated at 10%, but her foreign exchange expenditure for fuels necessary to sustain that growth has increased by 21% per year (Johnston 1978). Very little of the latter increase is attributable to increases in fuel costs rather than fuel quantities. An unpublished simple regression analysis by the Central Planning Office (Johnston personal communication 1977) shows that domestic sales of petroleum products during the period 1964–1976 increased only slightly greater than GDP in real terms. That analysis showed that the incremental relationship between fuel sales by quantity and GDP in real terms was as follows:

$$\Delta F = (\Delta GDP)^{1.06}$$

where F fuel = sales by quantity.

Because of the quadrupling of the price of crude oil following the 1973 Arab–Israeli war, Fiji has become much more concerned over an escalating fuel import bill and has begun to explore alternative indigenous energy sources. In July 1976 tax concessions were introduced to encourage conservation of electricity and the use of indigenous, alternate energy sources. Despite numerous queries, there has yet to be an approval under this regulation. A copy of the regulation is attached as Appendix 2. For Pacific Island countries, the accelerated increases in commercial fuel prices since 1974 are particularly onerous. Their energy consumption since 1950 has increased at an average rate of 11% per year (Johnston 1978) as compared to 7% for other less developed countries and 5% for the world average.

Investigations into alternative energy sources in other parts of the world indicate that apart from hydroelectric generation, the utilization of noncommercial energy sources (sun, wind, biomass, geothermal, tide, and oceanothermal) is still too expensive for large-scale use. These sources may, however, be utilized on a much smaller scale such as for small rural industries or in rural homes.

In the absence of sufficient information on patterns of energy use, particularly in rural areas, Fiji has not been able to formulate an overall energy policy. However, the May 1975 recommendations of an Alternative Energy Committee (set up on 8 July 1974) and contained in the Report of the Alternative Fuel Technical Committee, Central Planning Office, May 1975, and submitted to cabinet August 1975, have served as a broad guideline.

Purpose of the Survey

This survey was suggested by the Fiji Government's Central Planning Office, executed by the University of the South Pacific, and largely supported by the International Development Research Centre (IDRC). It is aimed substantially at fulfilling the need for more information on local needs and potential demand for energy in rural areas. New information in this report is to be made openly available to decision-makers and those affected by their policies so that all parties concerned with energy developments can base their recommendations on more information than was previously available. In the past, the Fiji Government's attempts to develop alternative energy sources in rural areas have been well-intentioned but were somewhat hindered by a lack of adequate information relevant to the needs and aspirations of rural peoples.

Need for the Survey

Fiji's population according to the 1976 Census is 63% rural. The Census definition of urban, however, includes much that is semirural, indicating an actually higher rural population than 63%. Most of this percentage is scattered in 3055 villages and settlements located over 200 inhabited islands. Many settlements are isolated.

Distribution of wealth favours urban areas. Urban drift results in rapid urban growth, which was approximately 5% between the 1966 and the 1976 Census compared to the national population growth of about 2% over the same period. The unemployment rate has increased steadily from 4.2% (1966 Census) to 6.5% (1973 Unemployment Survey) to over 10% (early 1978 estimate).

Despite rapid urban growth, Fiji's economy is still heavily dependent on agriculture, which accounts for 80% of the nation's foreign exchange earnings. Secondary industries have grown steadily, but labour costs — at a mean of $6.64 per day for wage earners in 1977 — and low efficiency of production in the manufacturing sector, make competition with goods from Asian countries extremely difficult. Consequently, the market for most manufactured products is limited.

To stem not only increasing unemployment, but also the increasing social ills that accompany high urban concentrations of human population, Fiji needs to develop both primary and secondary industries inside and outside urban centres. Increasing the comforts of rural living will certainly help retain would-be migrants to urban centres.

Any effective policy that attempts to alleviate one or more of the above problems must take serious account of inputs. Disproportionate increases in commercial fuel costs for small increases in economic growth rate would justify investigations for supplementary, if not substituted, indigenous energy sources on any scale.

Aims of the Survey

The aims of this university survey, agreed upon with IDRC, are:

1) To survey in selected rural areas, the present energy use and energy wants for improved living standards;

2) To survey alternative energy sources available and attempt comparative evaluation of the social and economic costs of developing alternatives in rural areas;

3) To assess economic and social viability of existing biogas systems and assess the advisability of expansion and biogas use in rural settlements; and,

4) To explore means of energy conservation in, and improve conditions of, domestic cooking in rural and semirural areas.

Methods

Information was obtained by a variety of methods and entered on data sheets. Interviews were supported by the completion of questionnaires that were filled in by the interviewer.

The data sheets and questionnaire forms were designed to provide information on:

— patterns of end use of energy;

— sources of energy for each end use;

— amount of energy expended for each;

— relative costs including cash and labour inputs of different energy sources;

— people's perceived energy needs for improved living;

— possible means of providing required energy locally, together with skills available and necessary for such developments;

— costs of diesel generation and biogas production; and,

— some assessment of social acceptability of innovations and of the prevailing economic and social conditions.

Methods of Assessing Present Energy Use

Selection of Areas

As we were looking for alternative energy sources and the possibilities for their utilization, we began by demarcating areas of different natural resources endowments. This enabled a rough overview to be gained of not only the kinds of energy resources available but also of the potential demand for energy use in any future developments.

The Fiji Islands were divided into four main groups as follows:

Group A

The two main islands, Viti Levu and Vanua Levu, are mountainous and volcanic, with relatively satisfactory road networks. They are also well endowed with natural resources both in terms of forests and agricultural production. These two islands contain about 90% of Fiji's population.

Rural settlements and villages on these two main islands are distributed as follows (interior refers to any settlement that is situated more than 16 km from the sea):

	Interior		Coastal		
	Road access	No road access	Road access	No road access	Total
Viti Levu	100	133	358	87	678
Vanua Levu	—	—	118	180	298

Group B

Large high volcanic islands that have some road network and are relatively fertile with some forests. These islands are not as heavily populated as the two main islands. Populations of these islands according to the 1976 Census are shown below within brackets. Village and rural settlements are: Ovalau, 27 (5831); Gau, 15 (2674); Taveuni, 19 (7710); Koro, 15 (3199); and Kadavu, 57 (7769). There are 133 villages with a total population of 27 183.

Group C

High volcanic islands with some parts over 77 m (250 ft) above sea level. No road network. Variable degree of fertility as gauged by forest stands and agricultural production. They are also more seriously affected by droughts than either of the first two groups. Villages and populations are: Matuku, 7 (1044); Moala, 8 (1946); Totoya, 4 (659); Yasawa Island, 6 (676); Taveya, 1 (37); Nanuyalailai, 1 (31); Nairai, 4 (707); Moturiki, 9 (682); Yadua, 1 (137); Nacula, 4 (598); Yaqeta, 1 (270); Ono (Kadavu), 5 (494); Beqa, 8 (1303); Waya, 4 (700); Naviti, 7 (1370); and Matacawalevu, 1 (296). There are 64 villages with a total population of 10 950.

Group D

Low limestone islands with no point over 77 m above sea level. They generally have poorer terrestrial resources than those in the other groups. Many of these islands face regular acute water shortages and have to be supplied by Public Works Department barges during periods of drought. The following are groupings of islands within different provinces.

Lau Group: Vanua Balavu, 16 (2446); Lakeba, 8 (2067); Cicia, 5 (1185); Ono-i-Lau, 4 (664); Kabara, 6 (627); Vanua Vatu, 1 (253); Fulaga, 3 (376); Nayau, 3 (490); Moce, 3 (544); Oneata, 2 (274); Ogealevu, 1 (142); Nasau, 1 (28); Tuvuca, 1 (196); Cikobia-i-Lau, 1 (70); Yacata, 1 (227); Vatoa, 1 (312); Namuka-i-Lau, 1 (483); and Komo, 1 (201).

Lomaiviti Group: Batiki, 5 (248).

Kadavu Group: Dravuni, 1 (87); Bulia, 1 (127); Matanuku, 1 (86); and Galoa, 1 (136).

Yasawa Group: Viwa, 3 (303).

There are 71 villages with a total population of 11 324.

Case Study Villages

Four villages were selected from the four main groups as follows:

Village 1 — Natia, Viwa Island, Yasawa Group. This village is a member of Group D. It has nine households with a population of 60. The choice of this village was influenced by the fact that it had temporary use of a 5 kW wind-driven electric generator. As a member of Group D, it has a very low terrestrial resource base.

Village 2 — Yaroi, Matuku Island, Lau Group. This is a member of Group C. It has 41 households with a population of 241. Its selection was influenced by the fact that it has a weather observation station, with some wind data collection.

Village 3 — Nacamaki, Koro Island, Lomaiviti Group. This village represents Group B. It has 42 households and a population of 312. Its selection was influenced by the fact that it has a diesel electricity generator.

Village 4 — Naqelewai, Naitasiri Province, Viti Levu. This is representative of Group A. It has 16 households and a population of 90. It has no means of communication by road or river. These were important factors in its selection from among other Group A villages.

Case Study Farms

Many of Fiji's rural people live in isolated homesteads on their individual agricultural land holdings. To obtain some information on the energy needs of these farmers seven case studies of individual farm holdings were undertaken. These represent Fiji's main farm types. An effort was made to include members of the two main races as follows:

Farm 1 — Indian: large pig farm with a biogas digester

Farm 2 — Indian: beef and dairy farm with a recently established piggery

Farm 3 — Fijian: cane farm with other commercial crops

Farm 4 — Fijian: tobacco and vegetable farm

Farm 5 — Indian: tobacco and vegetable farm

Farm 6 — Indian: cane farm on a recently developed government-supported farming project

Farm 7 — Fijian: cane farm on the same project as farm 6

Measurements of Present Energy Use

All common end uses of energy were identified and sources supplying various domestic end uses quantified. In addition, firewood used for other purposes such as copra drying, fish smoking, or bêche-de-mer processing was also weighed. Wherever wood was used, a small sample was taken for moisture content determination. These were dried at 100–105°C to constant weight (within 0.01 g).

Samples of three of the more commonly used fuelwood species were collected for calorific value determination in a bomb calorimeter at the University of the South Pacific chemistry laboratory. For every meal, firewood burnt was weighed to ± 0.05 kg; food cooked was weighed to ± 0.1 g and time spent noted. For every lamp used, fuel consumed was measured to ± 5 ml and period of burning noted. For other end uses, the quantity of fuel used and the period of use was similarly recorded. Fig. 1 offers some relevant illustrations.

Every household in the two smaller villages (Natia and Naqelewai) was monitored. Only 16 were selected randomly from the two larger villages (Yaroi and Nacamaki).

Energy Wants for Improved Living Standards

The expressed wants or desires of individuals are difficult to obtain without some influence from the interviewer and from the wording of the questions asked. We attempted to avoid having too much influence on the answers by using the questionnaires only as guides. The actual questions asked were left open-ended and interviews were kept as relaxed and informal as possible.

Fig. 1. *The firewood shown on the left is sufficient to cook a meal for an average family of six. The kerosene hurricane lamp (centre) is the most common lamp in rural homes. It consumes an average of 12.08 ml/h of fuel and is often kept on low throughout the night. Fish smoking is the traditional method of preservation. To smoke the 3.8 kg (fresh weight) of fish shown here (right) required 7.6 kg (air-dried) coconut husk.*

Methods of Identifying Alternative Energy Sources

Available Sources

Sun — Insolation data for Fiji have not been extensively collected. We did not attempt any measurements in this field. However, Dr J.F. Gabites, Director of Meteorological Service, outlined the state of knowledge of solar energy resources in the South Pacific and Fiji in a 1977 paper (Tables of Appendix 3 (a)). He quotes total radiation on a horizontal surface recorded at different stations throughout Fiji as ranging from minimum averages in June to 14 MJm^{-2} over Momi–Nadi–Lautoka–Ba–Tavua to 10–12 MJm^{-2} over most of Viti Levu and Southeast Vanua Levu. The minimum averages for most of the smaller islands, he estimates at around 11–12 MJm^{-2}. The summer averages (November–December) are higher. Over leeward northwestern Viti Levu, the average is about 21–22 MJm^{-2}; 16–19 MJm^{-2} for the rest of Viti Levu; 18–20 MJm^{-2} over northwest Vanua Levu; and more than 17–18 MJm^{-2} over most other parts of Fiji.

Wind — Wind speed data available are also insufficient for identifying energy potential. However, we did collect some wind speed data with a small portable air-flow metre.

Water — No monitoring of water flow, speed, etc., was taken, although we looked for potential hydropower use at all the areas covered in the case studies.

Organic rubbish — Possible sources of raw material for biogas production were noted at every case study area. Animal populations were recorded and all kitchen organic rubbish was weighed.

Wood — Fuelwood stands available to each case study were assessed using standard survey methods. Total wood volume of standing and dead fuelwood species was taken in representative quadrats of different forest types at each area. Quadrats were of the following sizes: 50 × 50 m quadrat, in a heavy mixed forest; 40 × 40 m quadrat, in a light mixed forest; and 10 × 10 m quadrat, in a single species dominated forest or in scrubland. (A sample data sheet for the above investigation is shown in Table 1.)

Methods of Assessing Social and Economic Factors

An attempt was made to assess the prevailing social and economic conditions that may be important in influencing not only the present but also the future demands for energy in our rural case studies.

Relevant information for this assessment was obtained both by data sheets and by interviews through questionnaires. Our data

Table 1. Sample of the fuelwood stand survey.

Yaroi — Matuku

Species: Common name	Species: Botanical name	Density group (kg/m^3)	Total volume (m^3)	Total weight (kg)
Quadrat 3				
Ivi	*Inocarpus fagiferus*	697	45.39	31636.8
Vesivesiwai	*Pongamia pinnata*	801	4.75	3804.8
Cibicibi	*Cynometra insularis*	801	5.7 (live) 5.72 (dead)	4565.7 2178.7
Quava	*Psidium guajava*	590	0.23	135.7
Tavola	*Terminalia*	590	7.69	4537.1

sheets recorded garden sizes, animal populations, house sizes, cash income, furniture, and other household and garden appliances. Our interviews recorded people's community obligations and organizations and their views and attitudes toward present rural living.

This section of the survey work has been the most uncertain. Our selection and treatment of the data are open to argument, and it is uncertain how generally applicable are the conclusions we arrive at. Nevertheless, the data collected do serve a useful purpose for this particular study.

We attempted to identify and weigh human qualities of self-reliance, innovativeness, initiative, and ambition. We decided that people's achievements and range of material possessions were probably the best available indicators of their determination and associated qualities. Thus, we devised a crude measurement system outlined in the section on Detailed Reports under Social Assessment.

The data collected on cash income through interviews often had a doubtful degree of accuracy particularly from subsistence farmers with erratic sales of a wide variety of products. This was, however, in most cases the only means available. In some cases our interviews were supplemented with more reliable recorded data from receipts or local cooperatives purchase records. For instance, each man's copra or coconut sale to the local cooperative shop was always recorded.

It was originally hoped that we would have access to the Fiji Government's 1977 Rural and Urban Household Expenditure Survey, but an analysis of that survey was delayed. Information from that survey would enable refinement of our crude rural income data.

People in rural areas obtain most of their basic needs cash free and are therefore not driven to note carefully, either mentally or literally, the various installments of cash that come to hand throughout a year. Thus, the estimates we finally obtained of their annual cash income are in varying degrees of accuracy and represent only 1977 cash income.

Biogas Survey

A list of existing biogas digesters was obtained from Fiji's Department of Agriculture, which has been responsible for building most of them. A questionnaire was drawn up for the farmers to fill in. Each farmer was also interviewed for his opinions on the merits and demerits of his biogas system. The biogas survey is reported in detail later.

Exploration of Means of Energy Conservation in Rural Cooking

A selection of low-cost cooking devices suitable for rural and periurban homes was tested. These devices were variously fueled with either wood, kerosene, or charcoal. A variety of common Fiji meals was cooked on them and both fuel consumption and cooking time noted. This work is reported in detail in the section on Comparative Tests of Selected Cookers for Rural and Semi-Rural Areas.

Duration of Field Work

Each visit to case study areas was of approximately 1 week duration. The field work, however, was scattered over 10 months. In every case we had the willing cooperation of the people. At every village, a general meeting was held soon after our arrival, and the aims of our survey were explained and discussed. These sessions were often lively and, for us, educational. They also enabled the villagers to understand better what we were looking for.

Survey Results and Discussion

Village Case Studies

Village 1 — Natia, Viwa Island

Land

This is one of three villages on the small limestone island of Viwa. The island's total area is only 465 ha of which 135.4 ha belong to the people of Natia. Of Natia's 135.4 ha, 17.8 ha are under gardens and goat pastures and approximately 29.7 ha under coconut. Scrubland dominated by vaivai (*Leucaena leucocephala* Linn.) covers some 87.4 ha while the primary beach forest still clothes some 0.6 ha of rough coral rocks. Most of the area is under 7.6 m above sea level.

Population

The age structure of 60 people in 9 households is shown in Table 2. Figure 2 represents graphically the age structure of the case study populations. Formal education for most of the villagers ended at upper primary school (after 8 years of primary education); however, there is a good selection of simple technical skills, self-taught, as summarized in Table 2. A large proportion of the village has migrated to other parts of Fiji, either temporarily or permanently.

Administration

Traditional — The village people are divided into two *mataqali* (land-owning units). The head of the *mataqali* is chief of both the village and the island. Presently the head is serving an interregnum and is yet to be installed, but his authority is much respected, and he presides over all village meetings.

Day-to-day running of village — An elected committee under the chief's chairmanship organizes the village. A *turaga-ni-koro* (elected official) is responsible for translating the committee's decisions to the village people. All village projects such as village farming, fishing, grounds-clearing, house construction, and shops are run by this committee.

Community projects

Natia is a closely knit, well-organized village with several ongoing projects. We were informed that none of the projects taken up by the village have ever failed through lack of interest or participation. Projects include:

Clearing of village green — A motor mower (away at the repair shop at Lautoka during our stay) keeps the village green short. All the village men also get together and cut grass regularly with cane knives.

Church — A large concrete block building of 14.8 m × 9.2 m had recently been completed. Over $F14 000 required for the church construction was raised partly by the village's annual fund-raising project (Adi Sede) and partly from the profits of its Vio shop (referred to later in this section).

Community water supply — A concrete well 3.1 m deep and approximately 2 m in diameter supplies the village with brackish water for cooking and for washing food and dishes. Water in this well rises and ebbs with the tide. Each household collects an average of three buckets (12–15 litres) of water a day from this well.

Fresh water is stored in two large tanks from which each household collects its biweekly ration (in the dry season) of government-barge-delivered water. A circular tank (donated by CORSO a New Zealand

Table 2. Village population statistics.

Village	Age distribution by sex: Age (years)	Male	Female	Education level reached by those who have left school: Level	Male	Female	Summary of technical skills available in the village		Other statistics	
Natia	60+	1	2	Navuso Agricultural			Carpentry	3	Average	
	51–60	2	1	College	2	–	Carpentry and boat		adults/home	4
	41–50	2	3	Methodist Leadership			building	2	Average	
	31–40	5	3	Training Centre	1	1	Women's traditional		male adults/	
	21–30	2	4	Nasinu Teachers			crafts only	9	home	2
	15–20	6	6	Training College	1	–	Traditional crafts and		Average female	
	11–14	1	4	F IV	1	1	sewing	3	adults/home	2
	5–10	4	2	F III	0	0	Simple mechanics	2	Able-bodied	
	1–4	7	3	F II	6	3	Wood carving	1	men (age 15–	
	under 1	0	2	F I	1	1			60)	17
		———	———	Class 6	1	4			Children still	
		30	30	Class 5.	3	1			at school	9
	Total	60		Class 4	1	0				
				Class 3	2	3				
				Class 2	1	1				
				Class 1	1	0[a]				
Yaroi	60+	13	4	Methodist Technical			Carpentry	9	Average	
	51–60	10	4	College	1	–	Carpentry and plumbing	1	adults/home	3.1(3)
	41–50	6	13	Nasinu Teachers			Communications		Average male	
	31–40	15	11	Training College (-FV)	–	1	mechanics	2	adults/home	1.7(2)
	21–30	11	18	F IV	8	1	Carpentry and boat		Average female	
	15–20	13	11	F III	1	4	building	1	adults/home	1.4(1)
	11–14	9	18	F II	29	19	Women's traditional		Able-bodied men	
	5–10	24	29	Class 7	1	0	crafts (all adults)	–	(age 15–60)	68
	1–4	15	14	Class 6	5	10	Women's crafts and		Children still	
	under 1	2	1	Class 5	0	0	sewing	36	at school	64
		———	———	Class 4	2	3	Wood carving			
		118	123	Class 3	0	0	(traditional)	1		
	Total	241		Class 2	0	0				
				Class 1	0	0				
				Level unknown	15	–				
				No formal education	2	–				

Nacamaki	60+	13	7	Teachers College	2	–	Carpentry	9	Average adults/home	3.9
	51–60	10	9	Mission School	5	9	Simple Mechanics	3	Average male adults/home	2
	41–50	12	9	F V	1	1	Plumbing	1	Average female adults/home	1.9
	31–40	13	15	F IV	6	7	Carpentry/mechanics/ plumbing	1	Able-bodied men (age 15–60)	85
	21–30	32	28	F III	3	1	Women's traditional crafts and sewing (all adults)	–	Children still at school	66
	15–20	17	18	F II	18	15				
	11–14	26	16	Class 7	7	2				
	5–10	18	21	Class 6	20	14				
	1–4	22	22	Class 5	4	5				
	under 1	3	1	Class 4	11	11				
				Class 3	1	5				
		166	146	Class 2	2	0				
	Total	312		Class 1	0	0				
Naqelewai	60+	4	1							
	51–60	0	2							
	41–50	6	4							
	31–40	1	3							
	21–30	13	10	–			–		–	
	11–14	3	4							
	5–10	8	7							
	1–4	7	5							
	under 1	2	1							
		47	43							
	Total	90								

[a] Level unknown –6.

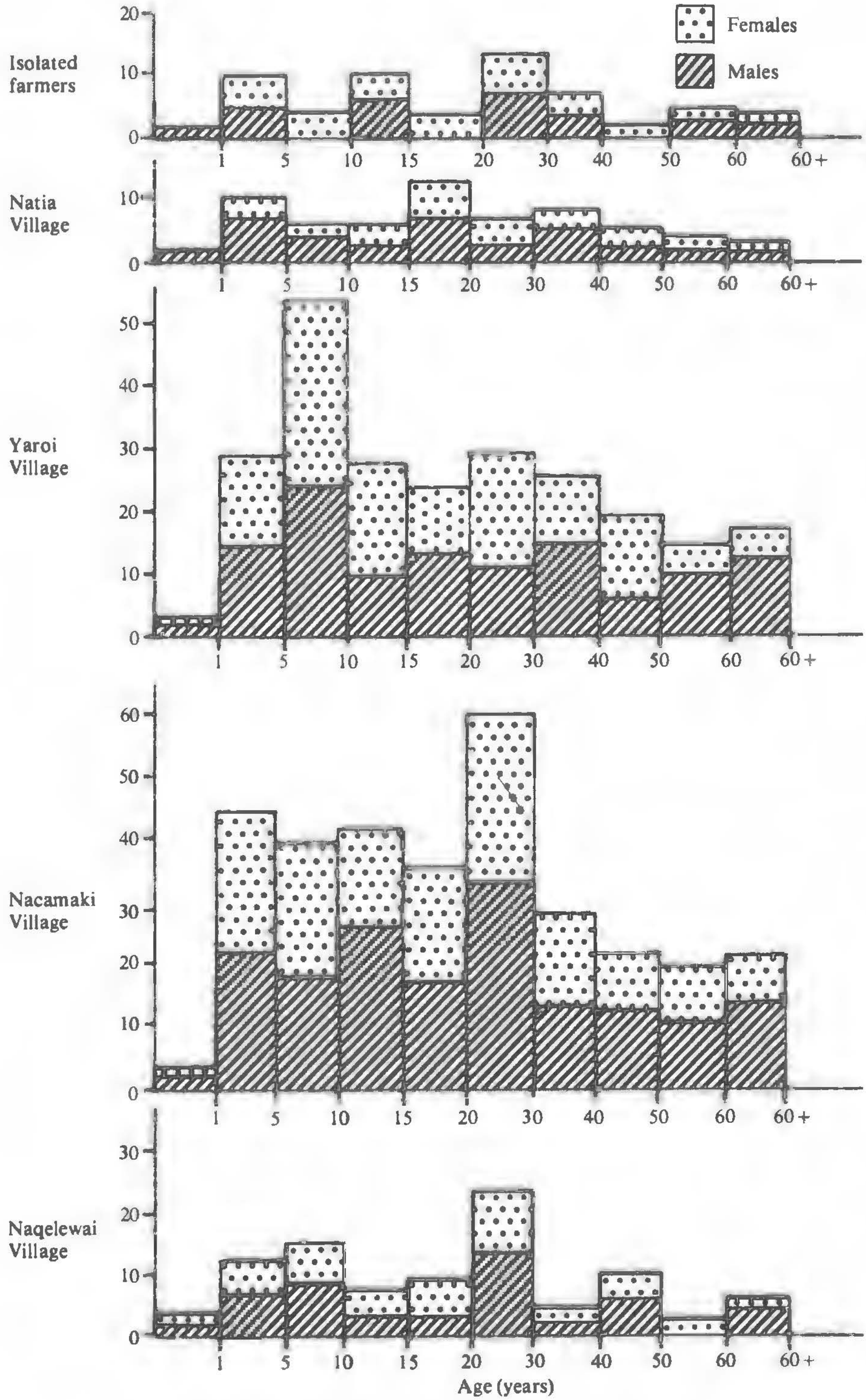


Fig. 2. *Case study population structures.*

based organization) of 29 546 litres capacity supplements the rectangular tank (30 348 litres) built by the village elders toward the end of the last century. The rectangular tank is built of lime and ash with plaited reeds for reinforcement and casing. Villagers report that this open tank will overflow during the wet season.

Sea water distillation is resorted to when fresh-water supplies run out. The community-owned water pipe leads from a 200-litre drum filled with sea water, down to the sea for cooling and back to the land for fresh-water delivery. According to our informant a bucket of sea water would yield half a bucket of fresh water.

Shops — The committee-run village shop at Natia makes a modest net profit of about $100 or more annually. This money is banked for small requirements of the village — such as running the motor mower — but also for emergency spending for the villagers themselves on occasions such as deaths and marriages.

A much larger village-owned shop at Vio (Lautoka harbour) serves at least 52 households and makes almost $1000 net profit every year. This shop has been running for some 17–20 years. A diesel generator, attached to the shop, generates electricity sold to Vio village and earns about $3600 annually. Profits from the Vio shop and generator go mainly toward payment of school fees and other necessary educational expenses for Natia children attending schools on the mainland.

Transport — A small 5.5 m cutter has regularly transported people and produce to Lautoka market (64 km distant) every weekend when wind conditions permit. Market trips for the village boat average 18 trips a year. The village now plans to purchase a larger boat to use both for deep sea fishing and for market trips to Lautoka.

On the main island of Viti Levu, Natia village operates a small lorry carrier business that investigations show is running very well.

Village generator — Through the government subsidized Rural Electrification scheme, Natia obtained a 6 kW generator, which was installed in May 1978, to supply lighting and power for a village ice-making machine, a village deep freeze, and a refrigerator.

Natural resources that provide cash income

The village earns annually approximately $7258 from the following sources: coconut (copra), $3907; fish (fresh smoked), $1000; bêche-de-mer, $500; agricultural crops, $381; sale of animals, $570; and handicrafts, $360. The total annual gross cash income per household is $806.

Village 2 — Yaroi, Matuku Island

Yaroi is one of seven villages on the island. It has 241 of the 1044 people of this 2797-ha island.

Land

Yaroi village's total land holding is approximately 1315 ha, of which 38% is under forests (both primary and secondary), 29% under coconut, 0.6% under gardens, and 32% under open grasslands. We were informed by the villagers that the dry grass-scrub areas, prevalent throughout the island, are generally the result of too frequent bush fires. Most of Yaroi's land is very steep. The whole island is hilly with four peaks rising to over 265 m. There are no constantly running streams. Water supplies are from underground wells and springs.

Population

The age structure of 241 people in 41 households is shown in Table 2 while Fig. 2 compares graphically Yaroi's population age structure to those of other case studies. Five- to ten-year-olds form a large proportion of the population. Able-bodied men and women (15–60 years) number 113. Those still at school total 71. Skills possessed include those in carpentry, boat building, and simple communications and mechanical maintenance work.

Administration

A well-run village, Yaroi has a government telecommunications centre, a medical centre, a primary school, and a government weather observation centre. Our survey considered only the village proper and did not penetrate into any of these ancillary bodies.

Traditional — The traditional chief of Yaroi and chief of the whole island of Matuku, *Tui Matuku* (King of Matuku), still retains a strong overall authority. The village has three *mataqali* (land-owning units). Decisions pertaining to the village are usually made at a meeting of village elders presided over by the chief.

Daily administration — A *turaga-ni-koro* (elected official) conveys the elders' decisions to the village people. At this village the *turaga-ni-koro* appeared to be no more than a conveyor of decisions, while at the other villages the officer was often the initiator of ideas and projects.

Community projects

Medical centre — The fine timber building that now forms the major component of the island's medical centre, was initiated and built by the islanders themselves with Yaroi village playing a major role. Only after the building was completed did the government concede to send a medical officer and nurse to run the medical centre.

Village school — A village primary school continues to be run jointly by the neighbouring villages of Yaroi and Natokalau. This requires frequent community fund-raising efforts. The *Tui Matuku* chairs the school committee.

Yaroi village school had to be rebuilt twice within the last 15 years following devastation by two strong hurricanes that hit the island during that period.

Village church — Like the village school, the village church is witness to the community's indomitable spirit against the forces of natural disaster. The old church was destroyed by strong hurricanes in 1975, but already the whole village, including those members working in other parts of Fiji, have gathered together enough funds and material to erect an imposing new concrete structure at one end of the village green.

Village cooperatives — Three small cooperatives, serving mainly the three separate *mataqali* members, each purchase and sell the village copra. Each of these cooperatives also runs a small shop. Like most cooperative groups throughout Fiji, the Yaroi coperatives have not been highly successful. The three existing ones grew out of one that was dissolved due to mismanagement. Only one of the three existing cooperative shops keeps careful and orderly records of all its transactions.

Community water supply — Severe drought conditions prevailed over the Fiji group at the time of our visit to Matuku. Fresh water, never an overabundant resource on the island, was strictly rationed in a well-organized manner. A community water supply system pipes fresh water from a natural spring at the foothills above the village and out through several community taps and showers distributed throughout the village. Water collection and showers were restricted to 2 h daily.

Natural resources that provide cash income

The village people derive their cash income, a total of $13 375, largely from copra and handicrafts. Village annual cash income from various sources is: coconut (copra), $8751; yaqona, $538; fresh fish, $249; agricultural crops, $297; sale of animals, not recorded; handicrafts, $961; and other, $2579. The total annual gross cash income per household is $326.

Village 3 — Nacamaki, Koro Island

Nacamaki is situated at the northeast corner of the fertile 10 409 ha island of Koro in the Lomaiviti group.

Land

Of the village's total holding of 575 ha, 246 ha are under gardens and coconut, 135 ha under grass and abandoned gardens, and 194 ha under forests (both primary and secondary). Coastal hills rise gently to a central plateau, allowing easy cultivation of most of the land. A road links Nacamaki to most other villages on Koro Island.

Population

Like the Yaroi population, the Nacamaki

population comprises an appreciable proportion of old people (over 60 years of age) and a large proportion of very young people (under 10 years of age). The age structure of 312 people in 42 households is shown in Table 2. There are a total of 164 able-bodied men and women (aged 15–60 years) and 70 school children. Fig. 2 compares the population structure of Nacamaki with the other case studies. Technical skills available in the village include carpentry, simple mechanics, and boat building.

Administration

A traditional chief has little authority and serves largely as a figurehead. Most of the decisions and the daily organization of the village are undertaken by the *turaga-ni-koro* and the village committee.

Community projects

Diesel generator — Nacamaki first installed a diesel generator to provide electricity to almost all the houses in 1975. This generator ran for 1610 h before it was replaced in 1976 by a larger one. The present 20 kW generator supplies electric lighting to 41 houses, two churches, one school, two teachers' houses, and one meeting hall, through 116 × 60 W incandescent light bulbs and 30 fluorescent tubes. The distribution of light bulbs and tubes, though uneven, has so far not created any discontent. Running costs for the generator are paid for by compulsory deductions from copra sales at the cooperative store. A half cent (0.5¢) is deducted from every two cents (2¢) that a pound (0.45 kg) of wet copra earns at the cooperative shop.

This system of payment distributes the burden of running the generator unevenly. Those who sell more copra to the co-op inevitably pay more toward running the generator. Further, the better-off villagers who can afford their own copra driers, sell very little copra to the cooperative, but ship instead direct to Suva, and appear to provide no other contribution to the cost of generating electricity in the village.

A general purpose power outlet at the chief's house enables the village to hold frequent evening meetings at a makeshift meeting hall (Vakatunuloa) close by. A lively village band with electric guitars, microphones, and amplifiers often keeps young and old entertained on Friday and Saturday evenings till the early hours of the morning.

School — Nacamaki village primary school takes children up to Class 6 at which they have an examination for entry into the local Koro Junior Secondary School. Villagers felt the heavy financial burden of running schools for the education of their children. Education emphasis at both primary and junior secondary level is still largely academic.

Churches — Both the Catholic and Methodist denominations have a strong following at Nacamaki. Two large church buildings serving either church dominate each end of the village. Church activities contribute to binding the community closer together and members of the different denominations cooperate closely for most church functions.

Women's interest club — A strong women's interest group meets in a special women's meeting house to learn sewing, cooking, child care, home health, and simple gardening. Products of such activities are sometimes sold at village fairs and members share the proceeds with the club.

School mothers' club — This club meets regularly to aid fund-raising activities for the school. The club helps in sewing school uniforms.

Church women's groups — Both churches have women's movements, but these are largely occupied with church related activities such as prayer meetings, visiting the sick, and catering at church gatherings.

Water supply — No continuously running fresh-water stream is located anywhere close to Nacamaki. The village water supply is piped from a spring behind the village and distributed to several community taps and showers scattered throughout the village.

Capital costs for both the diesel generator and the water supply are subsidized by the government. Prior to 1977 the village contribution to a diesel generation system was set at one-third total capital costs plus unskilled labour. Since 1977, village contribution has been one-sixth total capital costs plus unskilled labour.

Natural resources that provide cash income

The two major income earners are copra and yaqona as the list of various income sources indicates: coconut (copra), $10 571; yaqona, $17 152; fresh fish, $134; agricultural crops, $1376; sale of animals, $1598; handicrafts, $55; and other, $4153 (total $35 039). The total annual gross cash income per household is $832.

Village 4 — Naqelewai, Naitasiri, Interior of Viti Levu

A small village of 16 households, Naqelewai has been relatively isolated since it was settled because of its difficult terrain. The Wailoa River, which runs alongside it, is not navigable because of its numerous rapids. Roads skirted around the area until early 1978 when the first road link with the main island network came through.

Land

Naqelewai is nestled on the lower slopes of the narrow Upper Wailoa River valley. It is surrounded by steep mountains covered with rather well-leached soils. Pockets in the valley are more fertile. The village holding is about 269 ha of which 215 ha is forested, 37 ha under agriculture, and 17 ha under bamboo.

Population

Naqelewai's total population is 90 in 16 households. Information pertaining to this population is summarized in Table 2. A comparison of the age structure of the Naqelewai population with the other case studies is presented in Fig. 2.

Administration

Traditional — The chief of Naqelewai, is chief of Naboubuco — a district comprising three villages. His right to this position is not clearly resolved; however, he is revered and his authority is strong.

Daily administration — The chief and the *turaga-ni-koro* run the village jointly, consulting and advising the people through regular village meetings.

Community projects

Formerly the village women had three separate organizations that they have now merged into one. These three organizations have slightly different but overlapping functions:

Women's interest club — A government-run organization, this was begun by the district women's interest officer in 1962. From the information gathered by our survey, this group appears to concentrate on sewing and fund raising. It has already contributed $500 toward a village church.

Public health club — This club is concerned with general village hygiene. Completed projects include digging of a rubbish hole for each household; fencing of the village against animals, (wild or domesticated); and digging of a long open channel for the village water supply.

School mothers' club — This club was formed in 1972 to serve the local village school but has widened its activities to other village projects such as the establishment of a village health centre. The club is largely a fund-raising body that has so far raised funds for lawnmower and farming implements for the school; corrugated iron roofing material for teachers' houses; corrugated iron for health centre roofing; and timber and other materials for school desks.

Men's organizations — Only one men's organization exists. This is organized by the government agriculture department in an attempt to encourage the village men to plant more crops systematically. Tools, weedicides, and seedlings are provided by the agriculture department. Each member works to achieve a set goal of establishing at least 2000 plants of yaqona and not less than 1000 plants of any other crop every year. Tools are provided free for the first 12 years, but weedicides and seedlings are free only for the first 5 years.

The men of Naqelewai have not been instigators of community fund-raising activities for the school, church, or health centre; neither were they involved in initiating the digging of the rubbish pits or the fencing of the village. Women, the villagers agree, are the driving and active force for development in the village.

Natural resources that provide cash income

Lack of any easy means of transportation forces the Naqelewai villager to carry his produce on his own or his horse's back, over difficult terrain, to the nearest township approximately 37 km away. Any purchases made, come back the same way. The possibilities for enhancing income in the face of this arduous mode of transport is therefore very limited. Total village cash income from various sources is: yaqona, \$1625 and other, \$1525 (total \$3150). The total annual gross cash income per household is \$197.

Farm Case Studies

Equivalent information on the seven farmers selected for our case studies is tabulated in Table 3.

General Impressions

If the sample covered in our case studies is truly representative of Fiji's rural settlements, as we believe it is, then the overall impressions that we have gained can be generally applied.

Living conditions are generally not as comfortable as is possible in urban centres; they are, however, not harsh. The tendency is for dwellings to comprise a cluster of up to four separate houses rather than a single partitioned building. House wall materials include traditional thatching, corrugated iron, wood, woodtex, and concrete block. Roofing may be thatched (traditional bure) or made of corrugated iron, the most durable and most commonly used roofing material. The most widespread type of building material is wood, accounting for 48% of all living quarters surveyed. The kitchen is usually separated, either partially or completely, from the sleeping quarters. Of the total dwellings surveyed, 51% had detached sleeping quarters. House sizes vary from 6 m^2 to 104 m^2 with the greatest proportion (41%) measuring 3–7 m wide × 7–8 m long.

Home furnishings are simple but comfortable. Even though most people sit on the floor, and prefer to do so, the acquisition of chairs and tables is considered a necessity as a status symbol. Common household furniture consists of tables and wooden chairs (33% of homes), beds (69%), wire mesh

Table 3. The isolated farm case studies. (The average annual gross cash income per household for isolated farm case studies is \$16 304.)

Farmer	Farm type	Land holding (ha)[a]	Home population	Skills available	Some community involvement	Approximate gross cash income (\$)
1	Pig farm	—	9	—	√[b]	66300[d]
2	Beef and dairy cattle	104	10	Carpentry and welding	√	13500
3	Cane farm	7	10	Simple mechanics	√	3052
4	Tobacco and vegetables	12	13	—	√√[c]	7350
5	Tobacco and vegetables	8	6	—	√	3910
6	Cane farm	20	4	—	√	11440
7	Cane farm	10	—	—	√	8575

[a] All holdings are agricultural leaseholds except those of farmers 3 and 4 who are farming *mataqali* land.
[b] Membership of one or more community organizations.
[c] Office bearer of one or more community organizations.
[d] Despite this extremely high gross cash income this farmer is beginning to struggle under the burden of several bank loans.

food safes (55%), and dressing tables (33%). In the more well-to-do homes (10%) a variety of easy chairs was also found.

Water supply systems vary from community or individual tanks and/or wells, to community piped water supplies. Households with piped water to the kitchen, shower, and toilet represent only 2% of the total. Those with an attached tank represent 12% and those that only collect from a community tap and/or well, represent 86%.

Toilet facilities include flush toilet, water seal, or pour flush (WHO water-sealed) toilet, pit latrines, and the old method of using the bush, beaches, or river banks. Interestingly enough, despite a limited water supply, 7% of the homes in Yaroi have flush toilets. None of our other case study homes installed them. Thus, of the total households covered in our case studies, 2% have flush toilets, 54% use water-seal toilets, 36% use pit latrines, and 8% have none of these facilities.

Food is plentiful, but monotonous in both variety and preparation. Almost all of a week's meals in Fijian households, and a lesser proportion of a week's meals in the Indian households, are boiled. Fijians tend to cook more than they require for the reason, as a woman informed us, that unexpected visitors must always be anticipated at each meal. On the average 15.9% of what is cooked for a meal in a Fijian home is later thrown away as garbage. The Indian woman cooks differently. None of the Indian homes we surveyed produced significant leftover food thrown away as garbage. Almost all of what is cooked is consumed.

Every household we surveyed is closely affiliated in one or more ways to a local community, whether it be a village or a neighbouring settlement. Social interaction, therefore, is not lacking. Of the young people we interviewed 76% enjoy rural life. However, those factors given to us that make urban life more attractive are: easy means of transportation; available electricity for ironing, cooking, refrigeration, movies, and playing music; electricity for mechanical workshops for servicing machinery; better lighting; better educational facilities; and, better facilities and more opportunities for acquiring technical skills.

Present Energy Use

The total amount of energy that working members of a rural family have to provide is influenced by the size of the household, the calorific value of the energy source, and the utilization efficiency of the apparatus used. Table 4 summarizes the distribution of family sizes in the total population of our survey areas; Table 5 shows the calorific values of the common fuels used, while Table 6 lists the various apparatus utilized for the two major end uses of energy and estimates of their respective efficiencies. Findings in the last table suggest that there is much room for improvement in apparatus design to increase efficiency of fuel use.

Common domestic end uses of energy in rural Fiji are heat for cooking, baking, crop drying, food preservation, ironing, and light for illumination. The total energy consumed by a rural person's domestic activities is not significantly lower than that of an urban person as shown in Table 7 and Fig. 3. However, per capita use of that energy is much less efficient. The greatest proportion of energy used either by a villager or by a farming household member, is for cooking.

Common Rural Fuels

Wood

(1) Wood is the most commonly used fuel in rural homes not only because it is still plentiful but also because it is still usually free. Survey findings on the various end uses of wood energy are summarized in Table 8.

This table shows that isolated farmers only use wood for cooking, but villagers use it for a wider range of end uses. It also shows that people tend to favour a single species of fuelwood at each location. This choice is a function not only of the availabil-

Table 4. Distribution of family sizes in total population of survey sites.

Family Size	Natia	Yaroi	Nacamaki	Naqelewai	Farmers	Total
2	—	2	—	2	—	4
3	—	7	4	1	—	12
4	1	8	3	2	2	16
5	1	5	6	2	—	14
6	3	5	4	—	1	13
7	1	3	6	1	—	11
8	1	2	3	1	—	7
9	2	4	8	3	1	18
10	—	1	3	1	1	6
11	—	2	—	3	1	6
12	—	2	1	—	1	4
13	—	—	3	—	—	3
15	—	—	1	—	—	1
Total	9	41	42	16	7	115

Table 5. Energy values of common fuels used in rural Fiji.

	kcal/g	Equivalent kWh/g
Firewood (oven-dried)		
General[a]	4.7	5.462×10^{-3}
Vaivai[b]	5.25	6.102×10^{-3}
Quava[b]	4.96	5.765×10^{-3}
Dogo[b]	4.87	5.660×10^{-3}
Coconut shell[b]	4.56	5.300×10^{-3}
Commercial fuels[c]		
Kerosene	10.905	12.674×10^{-3}
Unleaded petrol (white benzine)	10.905	12.674×10^{-3}
Diesel	10.702	12.438×10^{-3}

[a] From Wiersum (1977).
[b] Determined by C. Wright, Chemistry Department University of the South Pacific.
[c] From Mobil Oil Company, Suva, Fiji.

ity of supply but also of the quality of the species concerned. Three of the more commonly used fuelwood species were tested and shown to have high calorific values: *Leucaena leucocephala* (vaivai); *Psidium guajava* (quava); and *Bruguiera gymnorhiza* (mangrove or dogo). Their calorific values are listed alongside their common names in Table 5.

Of the homes surveyed, 92% cook with wood over an open fireplace. A 1977 survey by the Fiji National Food and Nutrition Committee of 38 of Fiji's 59 boarding schools showed that 63.2% still cook exclusively over an open fireplace. Table 9 summarizes the results of that survey. That table shows that 89% of all schools surveyed use wood (either exclusively, or with other fuels) for cooking. The surprising widespread use of wood, even in urban schools 67% use wood, indicates that improvements in wood-burning technology would benefit a greater proportion of people than previously suspected.

The quantification of the different uses of wood showed that cooking accounts for the greatest proportion of wood energy use. The proportionate consumption of the various end uses of energy in our case study villages is summarized in Table 10. From our case studies data, we have attempted to estimate the overall wood consumption for various end uses in rural Fiji.

Table 10 also shows a rural person's total annual wood consumption at 506.26 kg (oven-dry weight). Of this, 353.37 kg (69.8%) is consumed by home cooking and general preservation, while 150.98 kg (29.8%) is consumed by wood-fired copra driers. We have assumed that all copra produced by nonplantation farmers (i.e., our small coconut farmers) is dried in wood-fired driers. Large copra farmers would use diesel-fired driers.

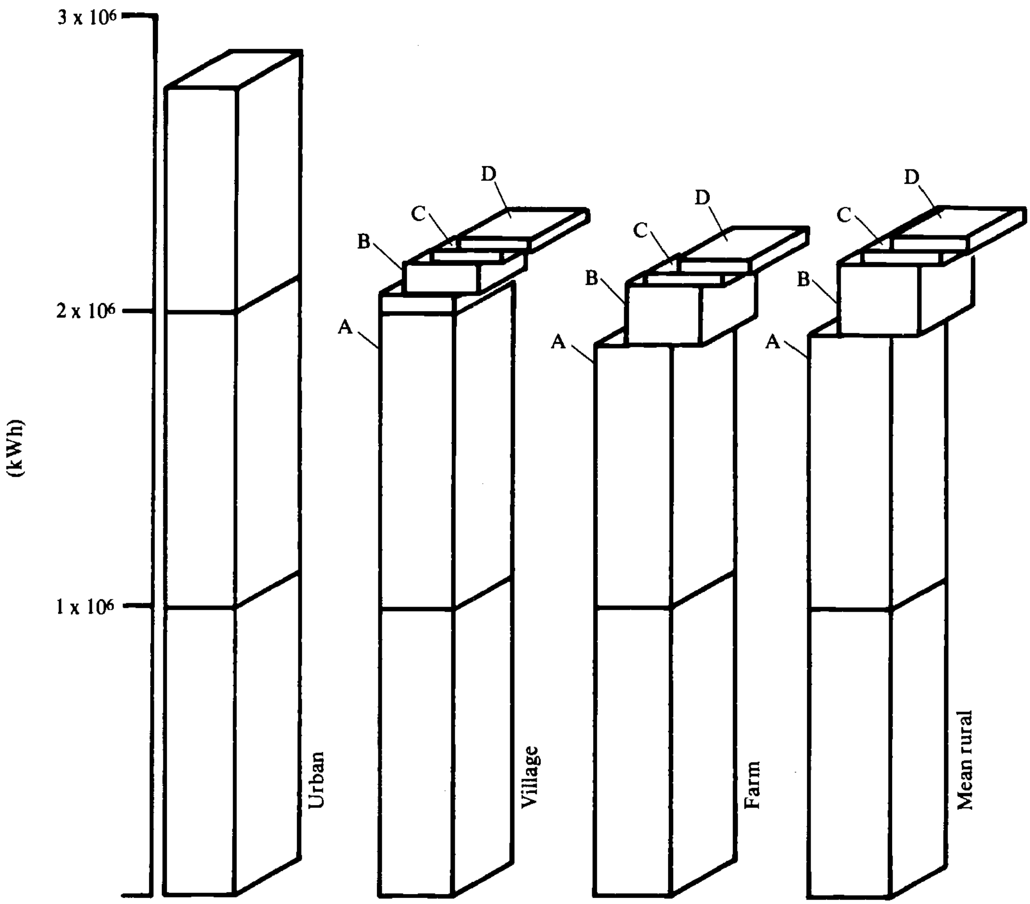


Fig. 3. *Annual average domestic energy consumption in rural Fiji. Urban refers to the total annual energy consumption per person in an urban family and is noted for comparison. The urban family uses electricity for cooking, refrigeration, ironing, lighting, radiogram, hot-water heating, two electric clocks, and an electric kettle. (A = cooking, B = lighting, C = ironing, and D = refrigeration.)*

The efficiency of different fuelwood used for copra drying is of interest. Our informants, at Matuku in Lau, claim that coconut husks and shells, which they now use, are much more satisfactory than mangrove, which they used before. The cooperative at Nacamaki, on the other hand, has switched from coconut husks and shells to vaivai logs, which the people claim are much better. Results of our survey support the latter contention. They show that 5861.5 kg (oven-dry weight) of coconut husks and shells is consumed for drying every tonne of dried copra at Matuku, but only 1035.02 kg (oven-dry weight) of vaivai will dry one tonne of copra in Koro. Weight for weight, vaivai is 5.7 times more efficient than coconut husks and shells. Some of this difference is probably because the Nacamaki drier is three times the size of the Matuku drier. The vaivai used at Koro had an average 39.5% moisture content (% moisture content = ((AD−OD)/OD)100, where AD is air-dry and OD is oven-dry weight) and a density of 978 kg/m^3.

A brief investigation of periurban and urban wood use showed urban wood consumption to be higher than expected. A survey of a 30% sample of homes on a major

Table 6. Fuel consumption and light intensities of some commonly used lamps in rural areas.[a]

Fuel	Type of lamp	Frequency (% of total lamps)	Light intensities in footcandles at 30 cm distance (mean range)		Volume fuel/h (mls)	Cost fuel/h (¢)
Kerosene	Standing	9	1.5 (0–4)		12.01	0.23
Kerosene	Hurricane	40	3.0 (1–35)		12.08	0.23
Kerosene	Tilly pressure	1	32 (20–70)		47.80	0.92
Benzine	Coleman pressure	11	Badly pumped 20 (8–25)	Well pumped 25 (20–45)	48.57	1.74
Kerosene	Empty fish can and wick	1	0.5		9.814	0.19
Electricity[b]	60 watt lightbulb	38	40			0.56[c]

[a] All light intensities were measured with an Avo light metre.
[b] Allowing for 30% efficiency in electricity generation and transmission.
[c] Fiji Electricity Authority (FEA) minimum price.

NOTE: (1) Recently introduced bottled gas "Gas" lamps run at 4.7¢/h (fuel cost); and (2) IES standards for various home activities are: 10 footcandles for passage ways, relaxation, and recreation; 30 footcandles for reading books, magazines, and newspapers; and 70 footcandles for working at the kitchen sink, handwriting, and study. These standards are extracted from Leckie (1975).

road out of Suva (Suva–Sawani–Nausori) showed that wood, along with kerosene, is still a major fuel for cooking. Some of these households claim to purchase wood at \$8–\$11/t (1977 prices), but others forage from surrounding secondary scrub lands. Estimates obtained from the Forestry Department and Suva's three main commercial fuelwood suppliers show annual wood sales in Suva (urban) of approximately 716 t for the past 2–3 years. Of this about 618 t is burnt in crematoria.

Assuming that Suva's squatter and periurban population would either forage or buy wood, as our above-quoted sample showed, we estimate urban annual per capita wood consumption at 87 kg (oven-dry weight). This gives a national mean of 350 kg/head/year wood consumption rate. The Government Central Planning Office estimates that at this rate wood contributes 19% of Fiji's total energy consumption. This figure is high when compared to a World Bank report estimate of 6% wood contribution to total support energy consumption at the world level, but it is low when compared to the same report's estimate of 48% for Southeast Asia and Oceania. These World Bank report figures were for 1974 wood consumption (Donaldson 1978).

(2) Past trends in wood use in Fiji — Records on wood consumption in Fiji are extremely limited. The Government Central Planning Office used our survey findings on wood consumption and used records of kerosene consumption through the years to make rough estimates of what the trend may have been (this is summarized in Table 11).

This table shows an increase in kerosene consumption and a decrease in fuelwood consumption per capita from 1946 to 1977. The pattern, we find, is repeated with increasing cash income of a family.

The Forestry Department's records show that the sale of fuelwood has decreased since 1945. Table 12 presents total volume of

Table 7. Domestic and subsistence energy consumption (kWh) of a rural person.[a]

End use	Fuel	Annual consumption		Daily consumption	
(a) Data from the case studies.					
		Village	*Farm*	*Village*	*Farm*
Ironing	Benzine	20	30	0.006	0.093
Lighting	Kerosene, diesel, and benzine	90	240	0.238	0.658
Refrigeration	Kerosene	20	20	0.058	0.094
Home cooking	Wood and kerosene	2070	1870	5.571	5.123
Other[b]	Wood	390	—	1.068	—
Total		2590	2170	7.041	5.968
(b) Using case study results and extrapolating average annual energy consumption (kWh) per person.[c]					
		per person		*per person*	
Ironing	Benzine	25		0.068	
Lighting	Benzine, diesel, and kerosene	172		0.471	
Refrigeration	Kerosene	25		0.068	
Home cooking	Wood and kerosene	1966		5.386	
Other	Wood	187		0.512	
Total		2375		6.805	
(c) Comparison of energy consumption (kWh) per person in two urban households in Suva.					
House 1 (3 persons)		*End point*	*Generation*[d]	*End point*	*Generation*
Ironing, Lighting, Refrigeration, Home cooking, Water heating		1600	5800	4.4	15.9
House 2 (9 persons)					
Ironing, Lighting, Refrigeration, Home cooking, Water heating, Radiogram, Electric clock		900	2800	2.5	7.6

[a] We have taken 1 kcal × 0.00116370 = 1 kWh (Int); 4.7 kcal/g (oven-dry weight) for wood, 10.905 kcal/g for both kerosene and benzine (specific gravity of kerosene = 0.819 and of benzine = 0.735 to 0.740 at 16°C).

[b] Other includes home preservation, copra drying, lovo bread baking, fish-smoking, and bêche-de-mer processing.

[c] In extrapolating, 52% weight is given to farm values and 48% to village values. This is based on the assumption that households greater than 2 ha live as the farmers do. The average village holding during the survey was 0.8 ha and 52% of the farm holdings in Fiji are over 2 ha (Agricultural Census 1968).

[d] Estimate of energy consumed at generation point assuming a 30% efficiency in electricity generation to the consumer.

fuelwood sold during 1945, 1946, and 1955. This information is fairly accurate because it is based on records of tax collected from the sale of fuelwood in those years.

The Central Planning Office estimates a slow decrease in per capita wood consumption at the rate of −0.6%/year accompanied by a relatively faster increase in per capita commercial fuel (oil and coal) consumption

Table 8. Major domestic and subsistence uses of wood energy and wood species utilized by the case study populations.[a]

	End Use					
	Home cooking	Lovo	Fish smoking	Copra drying	Bread baking	Other
Villages						
Natia (Yasawa)	V,c,h	V,n	V,C,H,n vu, br	C,H		V
Yaroi (Lau)	M,mo,tv,q,db, ta,dg,v,vn			C,H	C,H,q	
Nacamaki (Lomaiviti)	V,da,q,ma,mk, ta,mo,va,dm, uk,vx			V		
Naqelewai (Naitasiri)	Y,ku,k,dr,mo, ko,nu,bo,sa,tu, dv,q,md,mi,di,sr					
Farmers	Q,M,V,G,N					

Symbol	*Common name*	*Botanical name*
Bo	Bamboo	*Bambusa vulgaris* Schrad.
Br	Breadfruit	*Artocarpua altilis* (Pakinson) Fosberg
C	Coconut shell	*Cocos nucifera* Linn.
Cb	Cibicibi	*Cynometra insularis* A.G. Smith
Da	Dawa	*Pometia pinnata* J.R. and G. Forst.
Db	Dabi	*Xylocarpus grantum* Koenig.
Dg	Dogo	*Bruguiera gymnorhiza* (Linn.) Lam.
Di	Doi	*Alphitonia* spp.
Dm	Dalomate	Not identified
Dr	Drou	*Parasponia andersonii* (Planch.) Planch.
Dv	Davo	*Macaranga* spp.
G	Gliricidia	*Gliricidia sepium* (Jacq.) Steud.
H	Coconut husk	*Cocos nucifera* Linn.
K	Kauvula	*Endospermum macrophyllum* Pax and K. Hoffm.
Ko	Koka	*Bischofia javanica* Blume
Ku	Kukuluva	*Dillenia biflora* (A. Gray) Martelli ex. Dur. and Jacks
M	Mocemoce	*Pithecellobium saman* (Jacq.) Benth.
Ma	Makosii	*Cananga odorata* (Lam.) Hook. f. and Thoms.
Md	Midra	*Cyrtandra* spp.
Mi	Mimila	*Sauraia rubicunda* (A. Gray) Seem.
Mk	Molikaro	*Citrus grandis* (Linn.) Osbeck
Mo	Molau	*Glochidion* spp.
N	Nokonoko	*Casuarina equisetifolia* Linn.
Nu	Nuqa	*Decaspermum fruticosum* Forst.
Q	Quava	*Psidium guajava* Linn.
Sa	Sama	*Commersonia bartramia* (Linn.) Merrill
Sr	Sorua	*Alstonia montana* Turrill var. *montana*
Ta	Tavotava	*Macaranga* spp.
Tu	Tuva	Not identified
Tv	Tuvakalou	Not identified
V	Vaivai	*Leucaena leucocephala* (Lam.) DeWit
Va	Vavakada	Not identified
Vn	Venua	Not identified
Vu	Vutu	*Barringtonia* spp.
Vx	Vauwai	*Hibiscus tiliaceus* Linn. var. *tiliaceus*
Y	Yaqoyaqona	*Piper aduncum*

[a] A capital letter means that the frequency of use of the species concerned is greater than 15%, but a lower case letter means that the frequency of use is less than 15%.

Table 9. Use of cooking fuel at selected boarding schools in Fiji. (From a survey conducted by the Fiji National Food and Nutrition Committee in 1977.)

Cooking fuel	Schools Urban[a]	Rural	Total	%
Wood only	1	25	26	68
(wood used over an open fire)	(1)	(23)	(24)	(63)
Wood and kerosene	2	2	4	10
Wood and gas	1	1	2	5
Wood, gas, and kerosene	1	0	1	3
Wood, gas, kerosene, and electricity	1	0	1	3
Total of wood only or wood with other fuels	6 (67%)	28 (97%)	34 (89%)	
Kerosene only	1	0	1	3
Gas only	1	1	2	5
Electricity only	0	0	0	0
Gas and electricity	1	0	1	3
Total	9	29	38	100

[a] The Fiji Nutrition Committee followed the Fiji Education Department definition of urban and rural. According to that definition, all schools located on major road networks are urban. We have reclassified the schools to agree with our demarkations of urban and rural. These follow the 1976 Census, except that we have separated periurban from municipal authority boundaries of proper urban areas.

of 4.4%/year over the 27 years from 1950 to 1977.

(3) Social factors associated with wood use in rural area — Replies to our questionnaire seeking to identify some social factors associated with the use of wood are tabulated in Table 13. The table shows that all members of the family collect wood. Time spent in the collection of wood (dependent on geography), varies from 20 min for each bundle at Natia, where the fuelwood source is only 3–5 m distant at the nearest point, to 1.8 h/bundle at Nacamaki where the main fuelwood source is about 2.4 km from the village.

Most women found that smoky fires in their kitchens were irritating, therefore 53% of the open fires at Nacamaki and 75% at Yaroi were raised at least 40 cm off the ground under a broad corrugated iron chimney. This serves to funnel away most of the smoke from the kitchen. It is of interest to note that only 33% of women interviewed in the wet interior village of Naqelewai found smoke irritating. The possible effects of smoky fires on health are discussed later in this report, however, there is very little relevant recorded information available in Fiji.

Rural women spend most of their time on wood and food collection and on food preparation. A study of Nacamaki village by Bayliss-Smith (1974) showed that 73% of a woman's working a day is spent on domestic and food-gaining activities. Firewood collection is time consuming and physically taxing. The utilization of firewood is highly wasteful. Our tests showed that an open fire is only 5–10% efficient. An Indian survey quoted 17% efficiency (Chandola 1976). The heavy bundle of fuelwood must be carried in approximately 4 times every week regardless of the weather (see Table 13). The chore is one rural peoples would be glad to do less of. This is reflected in the swing toward kerosene for cooking when there is an increase in cash income.

Kerosene

(1) Domestic use of kerosene is mainly for cooking and lighting. A minor but increasing use is for refrigeration. From our survey findings we estimated that in 1977 in Fiji approximately 18 $\times$ 10^6 litres of kerosene was consumed for domestic cooking and approximately 3.6 $\times$ 10^6 litres was consumed for lighting. The greater proportion of kerosene consumption for cooking is in urban and periurban areas where electricity supplies lighting, but the greater proportion of kerosene consumption for lighting is in rural areas where there is little electrification.

Total kerosene consumption for refrigeration for the same year is estimated to be 0.952 $\times$ 10^6 litres, assuming the equivalent

Table 10. Different end uses of wood energy at case study areas, wood consumption per capita per year (in kg oven-dry weight).

Case study	Home cooking	Lovo[a]	General preservation[b]	Fish smoking and bêche-de-mer processing[c]	Copra drying	Bread baking	Total
Natia, Yasawa	412.97	4.12	10.4	178.98 31.28	824.41	n.a.[e]	1462.16
Yaroi, Lau	404.59	2.10	n.o.[f]	n.a.	1383.18	1.47	1793.36
lNacamaki, Lomaiviti[d]	366.95	2.10	0.27	n.a.	331.74	n.a.	701.05
Naqelewai, Naitasiri	283.13	n.o.	n.o.	n.a.	n.a.	n.a.	283.13
Isolated farmers	334.38	n.o.	n.o.	n.a.	n.a.	n.a.	334.28
Extrapolating to rural Fiji as a whole wood consumption per capita per year	353.37[g]	1.41	—	0.15[h]	150.98[i]	0.35	506.26

[a] Assuming only two lovo a year for each Fijian rural person. (This is the estimate given by villagers.)
[b] Includes: voivoi boiling, coconut oil cooking, food preservation for consumption, and clothes boiling.
[c] For commercial production only.
[d] At Nacamaki charcoal is used for ironing. One iron uses 530.4 kg of charcoal per year at 1.2 kg/h.
[e] n.a. = not applicable.
[f] n.o. = occurs but was not observed.
[g] Includes home cooking and general preservation.
[h] Bêche-de-mer processing only. There was no national data available for fish smoking.
[i] Assuming 60% national copra. The copra produced by small farmers is dried in wood-fired driers.

of 5.2% of all rural households possess refrigerators as indicated by our survey (noted in the section on Rural Energy Needs and Wants). It is evident from our studies that there is a definite switch to kerosene for cooking when there is an increase in cash income. (This is supported in our Detailed Reports.) Kerosene, a fluid, is easily transportable, is relatively inexpensive when compared with other commercial fuels, and can be utilized by less expensive equipment. Table 14 lists kerosene and benzine (unleaded petrol) prices and Table 15 lists the retail prices of various inexpensive kerosene cookers available for rural use.

Tests conducted in 1976 by the New Zealand Consumer Council on 13 common kerosene cookers sold in Fiji showed that though they were inexpensive ($2.90–$33.90) nine of them could not be recommended as safe. The comment on five of them was that they "should be neither sold nor used." The tests investigated efficiency of fuel use and potential fire hazard. A summary of the findings is presented in Fig. 4. According to these tests, the only relatively safe cookers are those coded D, H, I,

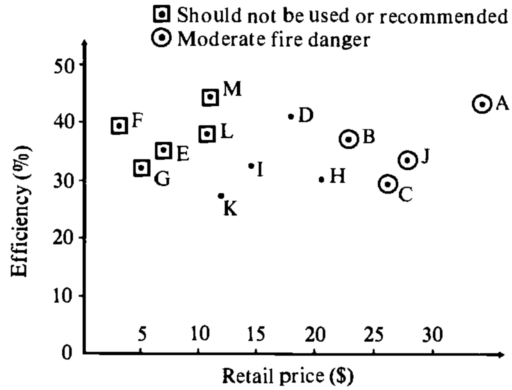


Fig. 4. *Summary of tests on common kerosene cookers (D, H, I, and K, passed).*

Table 11. Annual national wood consumption as estimated from CASD survey results and records of kerosene consumption. (Wood is expressed in kg oven-dry weight.)

	Year		
	1946	1956	1977
% urban population	15% Census	18% Census	37.3%
kg of wood/person	120	100	80
% rural population	85% Census	82% Census	62.7%
kg of wood/person	500	500	500
Mean kg/person/yr for country	440	430	350
Mid-year population	257400	339000	595000
Total wood consumption in kg × 10^6	113	146	207
Estimated kerosene consumption for all purposes in litre/person/yr	4.5	11.4	45.5

Source: Central Planning Office, Fiji Government, 1978.

Table 12. Wood consumption according to Forestry Department records on tax collected from wood sales (1.32 m^3 = 1 t). (All weights are of air-dry wood.)

	Year		
	1945	1946	1955
Wood source			
Inland wood	33864	33762	No
Mangrove wood	27030	27234	breakdown
Estimated Fijian use	4794	4284	
Total in tonnes	65688	65280	51000
Therefore kg/capita	253	261	151

Source: Central Planning Office, Fiji Government, 1978.

and K. These are the glass bowl, Hong Kong-made, torch single burner (D); the glass bowl, Canadian-made, coleman burner (H); the glass bowl, Hong Kong-made, solar brand (I); and the Swedish-made optimus primus (K). All of these are in the middle-price range, from $11.50 for K to $20.30 for H. Unfortunately, because they are cheaper, the unsafe cookers are purchased in much greater numbers as a 1976 Fiji Consumer Council survey showed.

Kerosene for lighting is utilized through a range of lamps. The most commonly used lamps are the most inexpensive but not the brightest. Retail prices of the various rural lamps are shown in Table 16.

Benzine (unleaded petrol)

(1) The better-off rural households invest in benzine lamps, which are used for homes, village meetings, and for night fishing. Benzine, because it is more expensive, contributes less to total rural lighting. Various contributions of the different light fuel sources in our case studies are shown in Table 17.

(2) Benzine is also used for ironing. This accounts for only 1.1% of a rural person's total domestic energy consumption. The coleman benzine iron has replaced the old charcoal iron to such an extent that we found the latter in only two out of all the households surveyed. A charcoal iron consumes a mean 1.2 kg/h of charcoal.

Rural peoples still depend largely on the free and easily available wood. There is, however, a definite tendency to supplement (40% of homes surveyed) and in a few cases (3.4% of homes surveyed) to replace wood with expensive commercial fuels.

Refrigeration and ironing are heavy consumers of commercial fuels. The village that owns the most irons and refrigerators has the highest total fuel consumption and Nacamaki, because it has a diesel electricity generator, has by far the lowest total commercial fuel consumption as shown in Table 17.

Rural Energy Needs and Wants

In response to a Cabinet directive, the Public Works Department of Fiji, in its rural electrification project, has estimated rural communities domestic power requirements largely in terms of lighting needs. Therefore, an allowance of 155 W per house is made to meet light requirements and cover line and other losses. It has been the policy to install generators in villages allowing an annual load factor of 27% for domestic use. The power yet unaccounted for could then be used for small village industries, for refrigeration, or other such uses. The village people concerned do not participate in determining the capacity and possible uses of their generators. (A discussion on the government's rural electrification program is presented in the section on Electrification by Small Autogenerators for Rural Communities.)

Our survey concentrated on domestic energy needs and gathered people's opinions through interviews and questionnaires. We attempted to make a qualitative assessment of people's energy wants and thereby provide some guidelines for possible future developments. Questions were directed at both female and male adults. In this report adults are those over the age of 15.

Questions were asked covering the following uses: cooking, lighting, heat for water, heat for warm air, and refrigeration. Questions on cooking were asked only to mothers of the households. Room heating is an important energy use only at Naqelewai, which is located in the centre of Viti Levu where the weather is relatively cool. The views of all adults were sought in our attempts to assess energy wants in lighting, water heating, and refrigeration.

Cooking

As already stated, rural cooking is *mostly* over open fires. Of women interviewed, 52.9% always cook over open fires. Of these, 71.7% use ground or Fijian type fireplaces. The rest of the women, 28.3% cook over raised or Indian fireplaces (Fig. 5). Open fire cooking is supplemented in 40% of the homes (Fig. 6). In most cases, the Hong Kong 10 wick kerosene cooker is used (Fig. 7). Two Nacamaki homes use LP gas stoves. Supplementary cooking facilities are used mainly under the following conditions: (1) during and after prolonged bad weather, such as hurricanes; and (2) when cooking is late. In only 3.4% of the households was there a complete substitution of open fire cooking by other fuels.

All women interviewed had heard of one or more alternative means of cooking either by kerosene, gas, or electric cookers. Of all women interviewed, 83.3% wished to have

Table 13. Some social factors associated with wood use in rural Fiji.

Village	RIFP[a] (%)	Mean collection time per load[b] (h)	Member of family who collects	Mean collection frequency per week	Users Male (M)/Female (F): Cooking	Copra drying	Fish smoking	% of women irritated by smoke[c]
Natia	0	0.5	Women mostly but also male members	4	F	M	F,M	83
Yaroi	75	1.5	Any members	4	F	M	n.o.	n.o.
Nacamaki	53	1.8	Any members	4	F	M	n.o.	91
Naqelewai	0	n.o.[d]	n.o.	n.o.	F	n.a.[e]	n.a.	33

[a] RIFP = raised Indian open fireplaces under a broad corrugated iron chimney.
[b] Total time taken to go to the bush, collect wood, and return home.
[c] Percentage of those interviewed in each village who claim that smoke is irritating to the eyes.
[d] n.o. = not observed but activity does occur.
[e] n.a. = not applicable as activity does not occur.

Fig. 5–10. *The Indian chula wood stove (5a) and a makeshift Bombay pot on the Indian chula stove (5b). An open fireplace (6). Two kerosene cookers, the Hong Kong wick (7) and the Swedish No. 1 (pressure stove) (8). Charcoal cookers (9a). The complete charcoal stove (9b). The modified Ghanaian stove (10a) and (10b) the oil drum oven of the modified Ghanaian stove.*

Table 14. Retail prices of common commercial fuels in case study areas (1977 prices).

Area visited	Price per litre (¢/litre) at the shop[a] Kerosene	Benzine	Notes
Natia, Viwa	20	41	Kerosene usually purchased in 18 litre drums from Lautoka
Nacamaki, Koro	32	49	
Naqelewai, Naitasiri	18	33	Naqelewai people usually purchase 18 litre drums of kerosene from town (Tavua)
Sigatoka	18	n.a.[b]	Kerosene usually purchased in 18 litre drums
Seaqaqa	27	47	
Periurban Suva (mean)	19	n.a.	
Suva (urban)	18 17.6 (bulk)	20	Many Suva people purchase in bulk (80¢ per 4.55 litres).

[a] Usually sold in 740 ml bottles where the customer provides the bottle.
[b] n.a. = not applicable.

Table 15. Retail prices of common kerosene cookers available for rural use (Suva retail prices).

	1976 ($)	1978 ($)
Single burner 10 wick	2.90	3.80– 6.50
Single burner 14 wick	6.75–7.50	7.70–11.69
Swedish primus No. 1	11.50	15.90–16.50
Swedish primus No. 2	14.00	16.00–33.00
Single burner flat wick	15.50	19.50–32.50
Double burners	—	32.00–34.95

better cooking facilities. This included all the women of Yaroi, Natia, and Naqelewai villages. They emphasized that: (1) collecting wood is difficult, especially in bad weather; (2) gathering wood and cooking over wood fires is time consuming. With the improvement in cooking facilities, time would be saved and this would enable the women to do other household chores such as weaving mats, making handicrafts, and fishing; and (3) open fire smoke is detrimental to the eye, (Table 13). Soot, they complained, makes pots particularly dirty and therefore harder to clean. Two Nacamaki women complained of painful eyes that even lead to sleeplessness in one case. Another woman from that village mentioned that she had to have an operation on one eye. It is rather surprising that women from Naqelewai, where people cook and sleep under the same roof, did not complain about open-fire smoke. Of all women interviewed, 10.4% were satisfied with their present cooking facilities. Although these women explained that wood collection is relatively easy, they complained that open-fire smoke was irritating to their eyes.

When asked "How do you cook mostly now?" the answers were influenced by ethnic group and location of case studies; for example, Indian women do a lot of grilling, frying, and boiling and their replies reflect this. However, replies from Fijian women were influenced by the location of the villages. Generally, island village women (Nacamaki, Natia, and Yaroi) said that they now cook mostly by boiling, baking, and frying. Yaroi women qualified their answers by saying that they boil food in coconut cream. Naqelewai women boil food in water, rather than in coconut cream, because coconuts are not available. Furthermore, they added that steaming and braising of food is done in the gardens, away from their houses. This is significant for this particular case study because it is common to have lunch in the field on week days. In addition, an occasional evening meal may be cooked in the field and brought to the village. In all case studies, except Naqelewai, most women would like to do more baking (of cakes, scones, etc.) in the future. However, women from Naqelewai are satisfied with their present mode of cooking.

Lighting

Sources of lighting in the case studies vary considerably from electricity to split bamboos. The percentage of households in the case studies that use different fuel sources for lighting is broken down as follows: 1.5%, electricity only; 24.2%, electricity and others; 42.4%, benzine and kerosene; and 31.8% use kerosene only.

(1) Electricity — Approximately one-quarter (24.2%) of the households in the case studies (a farmer and people at Nacamaki) enjoy the use of electric lights. As may be expected, these people are quite satisfied with the present lighting arrangement. The farmer is connected to a municipal electricity grid and therefore enjoys a continuous supply, but the people at Nacamaki had to be contented with periodic supplies from a village generator. Electric power is generated only on alternate nights for 5 h. When longer periods of lighting are required for traditional gatherings, etc., it is available at a cost of $1/h. When the power is off, hurricane lamps are normally used. A 5 kW Australian-made Dunlite windmill was installed at Natia village to generate power for lighting. During our stay there, it produced a total of 4.5 h of lighting over 11 nights. The windmill was unsuitably located within the village, and it was on the leeward side of the island.

(2) Other sources — Electric lighting is not typical of rural Fiji, but the combined use of benzine and kerosene lamps is common as 42.4% of the households use benzine and kerosene gas lamps. A substantial proportion (31.8%) of the case study homes light only kerosene lamps. In Naqelewai, we were informed that if fuels are not available, the family either goes to bed very early (daylight) or uses split bamboos for lighting. Dry bamboo is chipped into 1.2-cm wide stips, bound, and lit.

Table 16. Retail prices of common rural lamps in Suva shops.

Lamp	Fuel used	Retail price of lamps (1978 prices $)
Hurricane	Kerosene	2.80–5.00
Standing	Kerosene	1.50–6.00
Tilley	Kerosene	23.00–30.00
Coleman	Benzine	24.50–39.50
Gaz	Bottled gas	19.00–25.45

Table 17. Commercial fuel consumption for lighting at the case study areas (litres/head/year).

	Natia	Yaroi	Nacamaki	Naqelewai	Farmers
Benzine	1.5	9.7	0.2	1.0	1.7
Kerosene	10.4	6.9	2.4	8.4	4.8
Diesel (electric lights)	—	—	1.1	—	—
Total	11.9	16.6	3.7	9.4	6.5
Proportional fuel consumption and end use					
Lights	11.9	16.6	3.7	9.4	6.5
Cooking	0.4	6.0	0.4	0.4	0.4
Ironing	—	4.2	1.0	—	3.6
Refrigeration	—	5.9	0.5	—	0.4
Commercial fuel consumption	12.3	32.7	5.6	10.0	11.0

Fuel was available during the survey, therefore, we were unable to witness the use of that method of lighting.

There was a difference of opinion between the farmers and the villagers, on present lighting arrangements. Of the farmers, 42.8% were satisfied with the present arrangement (an average of one lamp, kerosene or benzine, per room). Of the villagers, 84.1% expressed disatisfaction with present lighting conditions. On average, there is one lamp to every house in village case studies. Benzine gas lamps are used for most activities before sleeping. Kerosene lamps are left on low throughout the night during sleep. All those interviewed were keen to find alternative sources of lighting.

The farmers that were investigated were rather interesting. For example, a wealthy Fijian farmer at the fertile Sigatoka Coast has had his house wired, light bulbs and fluorescent tubes fitted, and a refrigerator installed in expectation of connection to the main electricity grid in February 1977. However, even by the time of our survey, the connection had not been made, as the Fiji Electricity Authority (FEA) was working behind its scheduled program of rural electrification. An Indian farmer who raises pigs, goats, beef, and dairy cattle plans to buy a 5 kW diesel generator. He was quoted a price of $3700 for this particular generator. Another farmer, plans to buy a diesel generator after he has settled debts incurred in developing his farm.

In village case studies there was a marked similarity in the responses. Natia villagers were interested in electric lights only. In Yaroi, 72.6% of those interviewed were interested in gas lighting as an alternative. At Naqelewai, the general desire is for electricity. The village is near the Monasavu hydroelectric site and the preference for electricity may have been the result of constant exposure to activities related to this project. In Naqelewai, many respondents believed that a community system of lighting would work, while in Yaroi less than 30% held that opinion. The farmers were also pessimistic about community lighting. Those that support community systems of lighting said that (1) they can't manage one on an individual home basis, and (2) it will only work when properly supervised.

Apart from farmers, those that chose small household lighting units reasoned that (1) the average village is too big for a community system of lighting; (2) people are very different, i.e., they lack unity and common resolve; (3) there would be too many "bosses"; (4) there would be different consumption levels for different households making metering a necessity with administrative burdens; and (5) there would be maintenance problems, which would be difficult to overcome efficiently.

Farmers who generally favour individual lighting systems, claim they would be willing to contribute up to $671 per adult. This, obviously, would be quite a challenge for these farmers. In one household contributions volunteered by male members of the household were 90.9% of their annual collective gross income. When challenged about the credibility of their claims they reduced their possible contributions to an average of $240 per adult. This is still a high proportion of the family income.

Contributions volunteered by villagers on the other hand were much lower at an average of $125 per adult. They were nevertheless not too different. Some respondents would be willing to give 63.2% of their total income for the installation of a better lighting system. Again when challenged, their suggested contributions dwindled to $75 per adult. In Naqelewai, male respondents were careful with their answers when asked how much they would be willing to contribute. They responded by saying that what they would contribute would depend on the allocation from the village council.

Although respondents were unsure of the amounts they would contribute, they had definite reasons for improved lighting. Parents, claimed that with better lighting their children would study properly and perform better at school. Fijian women in particular said that better lighting facilities would enable them to do other jobs such as plaiting more mats. Youths claimed that such a project would increase social gatherings.

Heat for Water

The majority of the people interviewed (91.3%) wished to have hot water supplied to their homes. For the few that thought otherwise the reasons were: (1) Fiji's climate doesn't necessitate the use of hot water; (2) where rivers are nearby bathing is enjoyable and satisfactory; and (3) hot-water supply in homes is a luxury that only few have heard of.

Those that desire hot water would use it for cooking, washing, bathing, and steam baths. Steam baths are normally used in villages for medicinal purposes. Contributions for a hot-water system ranged from $40 per adult at Naqelewai to $700 per farm adult but averaged $287 per adult. This is high for villagers whose mean average annual household gross cash income is $543. Farmers' household annual average gross cash income is $16 304. Annual gross cash income per adult is therefore $155 for villagers and $5435 for farmers.

Heat for Warm Air

Except for the Naqelewai villagers, not all case study householders warm their homes in the cold season. The comment is that all one needs is an extra blanket or two. At Naqelewai, houses (traditional thatched homes called bures) are kept warm by burning wood. (Those who live in homes with sheet iron roofing do not warm their houses due to copious condensation.) Apart from warming the house, the fire improves and strengthens the thatching on a Fijian bure through constant drying.

The duration of air heating in the homes during a year ranges from 1 to 6 months, but the average is approximately 5 months. All respondents were eager to improve their heating conditions. When asked how they would go about improving their home heating conditions the answers were to (1) use more blankets; (2) have proper ceilings for the home (present practice involves arranging whole bamboos very closely or installing sheets of plaited bamboos under the corrugated roof); and, (3) use timber instead of thatching for walls.

One-third of the people interviewed chose electricity to improve heating conditions in their homes. From the interviews we learned of three main obstacles to the possible improvements that had been proposed, namely: (1) financial constraints; (2) transportation difficulties; and (3) the absence of relevant technology.

Refrigeration

Refrigeration is not new to Fiji's rural people, but only 5.2% of the households in the case studies possess refrigerators. All refrigerators in the case studies are kerosene fueled. Not many village people were interested in sharing community refrigerators. Only in Naqelewai was there a strong desire (73.7% compared with 10% in Nacamaki and 22.2% in Yaroi) for community refrigeration. Greater enthusiasm (90.2%) was shown toward individual ownership of refrigerators. Those who were pessimistic about community refrigerators gave the following reasons: (1) problems would arise over the right of use; (2) the greater number of users would result in rapid wear and tear; and, (3) there would be maintenance problems.

Many reasons were given as to why refrigerators had not been acquired. These included:

(1) Financial constraints. Some farmers are presently repaying loans for the development of their farms and in one case for a tractor. A large proportion of those interviewed said that the initial costs of refrigerators were too high.

(2) Naqelewai people also mentioned the transportation difficulties.

(3) Some farmers said that they would like to tackle farming first.

(4) Fuel is expensive. In Yaroi, a woman complained that her refrigerator uses 6 bottles (740 ml/bottle) of kerosene in 4

days. She feels that at $1.20 for 4 days, this is too costly. People from this village were very enthusiastic about biogas. Many people said that they would buy refrigerators if they were run on biogas or on less expensive fuels than kerosene.

Those interviewed were prepared to give an average of $167 for the installation of a refrigeration plant.

Indigenous Energy Sources and Potential

Although studies (Johnston 1977; Medford 1977) have shown that the use of most indigenous energy sources on a large scale is still not practicable for Fiji, their use on a small scale for rural communities has greater possibilities. There can be no common answer for different rural settlements. Not only are there considerable variations in the availability of resources, but the energy source most suitable for any particular settlement is dependent on the location of the settlement with respect to the energy source.

Wood

Results of our survey tabulated in Tables 18 and 19 show that wood is still plentiful in all the villages but not all the farm case study areas. This situation is representative of rural Fiji. It is expected, however, that because the farmers studied are leaseholders, maximum returns on investment would be sought partly through clearing their holdings of forest as quickly as possible. Their situation will rapidly equal that of the Sigatoka cane farmer, whose fuelwood is now supplied only by regular prunings of his fast-growing fenceposts (*Gliricidia sepia*). Only beef and dairy farmers will still have more than sufficient fuelwood supplies from pasture shade trees.

In most of rural Fiji, fuelwood is foraged from forest deadwood. The level of demand that necessitates the felling of live wood could not be determined for any particular case, as time did not permit monitoring of deadwood production rate in the forests concerned. However, Table 18 shows that if felling of live trees from standing forests (both primary and secondary) were the only method of collecting fuelwood, and assuming a 15-year regeneration cycle, existing forest stands could sustain from 5 to 12.7 times the present levels of consumption. (Fiji's Forestry Department would use a shorter cycle (8 years) for cultivated fuelwood forests in Fiji, but we have assumed a 15-year cycle for the slower secondary forest regrowth.)

Measurements of forest densities show that fuelwood volumes per square meter of area vary from 0.01 m^3 to 0.05 m^3 for denser primary forest and from 0.003 m^3 to 0.03 m^3 for secondary forest. Soil tests results listed on the same table, show that the area with the richest soils (Nacamaki, Koro) produces a secondary forest just as dense as the primary forest in fuelwood stock.

To estimate total wood weight available, fuelwood species were grouped into three different density groupings as follow:

Group I
Mean density 801 kg/m^3
Cynometra insularis
Intsia bijuga
Pongamia pinnata
Terminalia cattapa

Group II
Mean density 697 kg/m^3
Barringtonia spp.
Bischofia javanica
Cordia subcordata
Ficus barclayana
Glochidion spp.
Inocarpus fagiferus
Macaranga graeffeana
Mangifera indica
Samaea saman
Trichospermum

Group III
Mean density 590 kg/m^3
Cerbera manghas
Commersonia bartramia
Desmodium umbellatum
Ficus tinctoria
Ficus vitiensis

Grewia spp.	*Psychotria* spp.
Leucaena leucocephala	*Vavaea megaphylla*
Morinda citrifolia	*Piper aduncum*
Parasponia	*Premna taitensis*

Table 18. Firewood stands available to the four case study villages.

	Natia	Yaroi	Nacamaki	Naqelewai
Population	60	241	312	90
Total holding (ha)	135	1315	575	269
Under agriculture (ha)				
Gardens	4	8	246	24
Plantations	30	386	—[a]	14
% holding under forest	65	39	34	80
Soil conditions (Analyzed by Fiji Agriculture Dept)				
pH (water)	7.1–7.2	5.9–6.9	6.1–6.8	5.1–5.6
Total available nitrogen (%)	0.41–0.48	0.08–0.30	0.45–0.49	0.18–0.29
Total available phosphorus (ppm)	7085–7892	62–530	66–11022	32–278
Total available potassium (m.e. %)	0.82–1.35	0.32–1.31	1.06–1.52	0.05–0.17
Total available calcium (m.e. %)	>400	7.60–37.50	12.08–18.97	1.03–11.64
Total available magnesium (m.e. %)	13.13–15.96	7.89–10.12	3.86–9.93	0.33–2.72
Wood stands				
Primary Forest				
Area (ha)	0.6	321	165	69
Wood volume (m^3)	303	54298	40753	3525
Tonnes dead wood (oven-dry weight)	3	64	62	n.a.[b]
Density (m^3 wood/m^2)	0.05	0.02	0.03	0.01
Secondary Forest				
Area (ha)	87	184	30	146
Wood volume (m^3)	4505	16064	10251	4140
Tonnes dead wood (oven-dry weight)	303	23	16	n.a.
Density (m^3 wood/m^2)	0.01	0.01	0.03	0.003
Present total annual wood consumption (tonnes oven-dry weight)	38.265[c]	98.853[c]	218.728	30.319[d]
Wood area (ha) required/ person assuming 15 year regeneration and using secondary forests only	0.29	0.19	0.11	0.51
Sustainability of consumption at present levels by present wood stands assuming 15 year regeneration	×5	×12.7	×8	×8

[a] Grasslands and pastures.
[b] n.a. = not available.
[c] Does not include coconut wastes as fuel.
[d] Under estimate.

Densities, as available, were extracted from Berry and Howard (1973). Those of unknown densities were assumed to have the same density as their known closest botanical relatives. All small trees and shrubs were placed in the third group. To estimate the oven-dry weight of standing wood, the results of drying tests conducted on collected samples were taken. These gave an average oven-dry weight of 55.9% of the fresh weight, which is a moisture content of 78.9% (% moisture content = (fresh weight − oven-dry weight/oven-dry weight)100).

As primary forests are cleared, regrowth is more likely to reflect secondary forest densities, as data in Table 18 shows. Thus, estimates on land requirements per head have been based on secondary forest data. Estimates of wood area requirement per person shown in Table 18 assume felling of live secondary forest trees only. Under this condition, wood requirements for one person at present consumption levels would denude from 73 m^2 to 340 m^2 of secondary forest every year in the various case study villages.

Hopefully, live felling over most of Fiji will not be necessary before improved fuelwood utilization technology and good management schemes are devised. Environmental costs in terms of loss of soil fertility, soil erosion, disturbance of natural drainage systems, and reduced ground water retention can be serious. Furthermore, the loss of primary forests will deprive rural people of the benefits of native species for food, shelter, medicine, and other uses. We estimated, from information gathered from rural peoples, that the distribution of useful native vascular plant species in Fiji's native forests are as follows: approximate total "native" vascular plant species in forests, 2120; uses for man (% of total species)

Table 19. Wood stands available for fuelwood for the isolated farmers.

	Farm type			
	Beef/dairy cattle	Vegetables and tobacco	Vegetables	Cane and vegetables
Population per household	11	9	7	10
Total land holding (ha)	103.68	12.15	8.1	6.89
Under agriculture	All scattered	11.745	6.48	6.70
Under forest	shade trees	0.405	1.62 (scattered trees and shrubs)	—
Wood stands				
Primary forest	—	—	—	—
Secondary forest and bush	Mixed species	Quava only	Mocemoce, quava, and yaqoyaqona	*Gliricidia* fence posts
Live wood volume (m^3)	636	9.55	3.28	
Equivalent tonnnes oven-dry weight	1600	3.155	1.084	
Tonnes dead wood	378	Negligible live wood felled	0.102	—
Wood area/person (ha)		0.045	0.23	
Present annual wood consumption per person (kg oven-dry weight)	462.89	241.87	305.69	32.9
Years left to complete clearance of standing wood (assuming only clearing is for fuelwood)	40	1.19	0.5	Fence post prunings not sufficient for total demand

medicinal, 5%; food, 2%; shelter, 10%; and other, 5% (introduced plant species are not included).

The only case study village where live felling of fuelwood occurs is at Nacamaki. Here vaivai is felled to fuel the copra drier. Its removal does not involve clear felling. Vaivai, an introduced secondary forest species, grows among coconuts and other trees so that its removal does not completely obliterate the canopy. Even where vaivai occurs in clear stands, felling is selective. This practice is labour intensive, however, labour is not scarce in rural areas.

Future Fuelwood Supply and Demand

When an increased dependence on fuelwood supplies for future energy sources is considered, an account must be taken of the priorities of land allocation for alternative uses. Over the two main islands, and some smaller islands, much of the land has been subdivided and leased for individual farming. Almost all such land will eventually be cleared of forests. The 1968 agricultural census listed 51% of all Fiji's agricultural land holdings as leasehold and 29.5% *mataqali*-owned. Nonformalized holdings on *mataqali* land are more frequent in the smaller islands, whereas leasing is becoming the rule on the two main islands.

Villages

Around villages, what is not leased is left for the landowners' (villages') use. In general a villager earns most of his annual cash income from the sale of crops. Our survey data show that a mean 74% of a villager's annual cash income is from the sale of crops. Traditional methods of slash, burn, and shifting agriculture are still widely practiced. A used plot of land is left to fallow (during which time the soil fertility is somewhat restored) before it is used again. The length of time a plot is left to fallow is dependent on the ratio of population to available land.

Where a forest, primary or secondary is cleared for gardens, some of the felled wood will be utilized for fuel, but most of it is decomposed faster than the fuel foraging rate. Firewood collection thus continues from surrounding forests.

A rural person, therefore, needs land not only for food and cash crops but also for fuel. Working from the data on Table 18, and taking 5 years as the maximum fallow period for a plot of land to retain a satisfactory level of soil fertility, land requirements per person for agriculture and fuel in the case study villages are as listed in Table 20.

With this information the population level at which the demand on available land becomes critical can be estimated. The critical demand level is defined here as that which allows a plot to remain fallow for 5 years before it is cropped again. Beyond this level, land is reused in less than 5 years resulting in accelerated soil deterioration and diminishing fuelwood supplies. The latter effect is due to the inability of even the fast-growing secondary shrub species to reach maturity in 4 years or less.

Assuming that present stands of primary forests will be left untouched (most of them are on land too steep for present methods of use), the number of years calculated to reach a critical level of demand for the village case studies has been estimated in Table 20.

The years listed in Table 20 represent a lower limit to the time required to reach a critical level of demand as their estimation did not include the practice of deadwood foraging, which is currently widespread. Assuming that the land requirements are the same for the broad resource regions, of which the case studies are representative, estimates of the number of years to a critical demand level for Fiji's smaller islands are as shown in Fig. 11. These estimates show only two islands at critical levels (0 years). However, the effects of pressure on the land on these two islands will probably take several years to become apparent as our estimates did not include deadwood foraging and migration.

Isolated Farmers

The land use situation for isolated farmers

Table 20. Land requirements per person for agriculture and fuel in the four case study villages (ha).

	Natia	Yaroi	Nacamaki	Naqelewai
Land required for fuelwood per person	0.3	0.2	0.1	0.5
Land required for crops per person	0.3	0.2	0.7	0.3
Total land available per person under secondary growth and coconut plantation (L)[a, b]	2.0	2.4	0.9	2.0
Total land requirement per person (l)[b]	0.6	0.4	0.8	1.8
Estimated rate of population growth (g)[b]	0.025	0.025	0.025	0.025
Number of years (y)[b] to critical level of demand	48.8	72.6	4.8	4.3

[a] Coconut plantations are here considered only for garden area and not as fuelwood source. On average, one hectare of coconuts will produce 4400 nuts/year. Nut shell and husk can be used for fuel. Every hectare of coconuts produces an average of 0.4 t of shell and 1.0 t of husk per year. Using shell alone this is 1.6×10^6 kcal/ha/year.

[b] Rate of growth of the Fijian (native) population during the 1966–1976 intercensus period was 0.025 (2.5%). It is assumed that natural growth of village populations will remain at this level. In actual fact it probably will decrease further. Thus, the assumption in algebraic terms is that at critical level $l\ (1+g)^y = L$ or $y = (\log\ (^L/l))/(\log\ (1.025))$, where l = total land requirement per person, g = estimated rate of population growth, y = number of years to critical level of demand, and L = total land available per person under secondary growth and coconut plantation (derived by D. Medford, CASD).

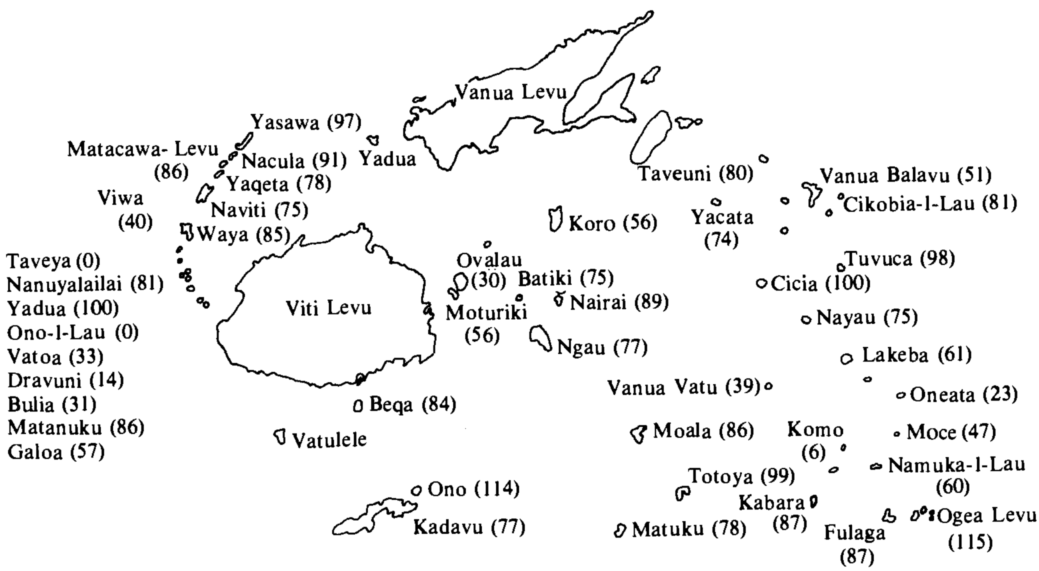


Fig. 11. *Estimated years to critical land use level on small islands of Fiji. (Years to critical level of use at existing land use patterns are noted in brackets.)*

is different. Small leaseholds for commercial cropping are expected to be rapidly cleared for full utilization. If the farmers are to continue using wood for cooking at current levels, fuelwood cultivation as fenceposts and/or on embankments should be considered.

Expanded Utilization of Wood as Fuel

Fiji Forestry Department studies (Frith 1978) show that Fiji has enough standing timber area (native and exotic) to produce waste wood of a volume large enough to contribute significantly as an energy source. Table 21 shows the areas of exotic and natural wood plantations throughout Fiji. Estimates (Johnston 1977) show that a single hectare of mature pine (15 years old) will produce over 56 000 kg of wood waste when cut, i.e., 4.2 kcal/g at 12% = 235 × 10^6 kcal.

As a rural energy source, wood may be used (1) by direct burning as is presently done (mostly for cooking); (2) for electrification through steam turbines; (3) for electrification by producer gas; and, (4) as charcoal for direct burning or electrification.

(1) Wood for Cooking

Cost estimates by Fiji's Central Planning Office in 1976 of wood waste are shown in Table 22. For the purpose of illustration we have added a fifth column to show what these prices would imply for a family of six in Suva. It should be noted that mangrove wood price includes the value of seafood that would be lost with wholesale cutting of

Table 21. Analysis of natural tree cover (Frith 1978).

Forest category	Land ownership (ha)					
	Private	Crown	Forest reserve	Leased to F.D.	Communal	Total[a]
Production forest (unexploited)	16024	6107	987	3803	226312	249171
Production forest (exploited)	4224	1273	2271	171	38775	50856
Conservation forest	10941	18088	13580	71	208021	250721
Noncommercial forest	13619	16776	719	958	219757	251828
Mangroves	—	18400	—	—	—	18400
Timber plantations	—	50	1000	8450	—	9500

[a] Timber plantation is not strictly speaking "natural tree cover" but includes those plantations that have been established on forested land, usually exploited production forest. It does not include pine plantation on open land, which amount to some 33 000 ha.

Table 22. Approximate cost of wood waste (Fiji dollars per air-dry tonne, 15% moisture).[a]

Wood	At site	Transported 20 km	Transported to Suva	Annual fuel bill for a family of six at Suva prices
Coconut	4.00	7.50	15.0	41.4
Hill forest	10.40	—	17.40	48.0
Mangrove	50.00	—	55.00	151.8
Pine	5.50	11.40	18.90	52.2

[a] Results of our survey show a mean 400 kg/head/year (oven-dry weight) consumption of wood for cooking where wood is the only cooking fuel. Thus, annual requirements for a family of six (average household size) = 400 × 6 = 2400 kg (oven-dry weight) = 2.4 t/family/year at 15% moisture content air-dry wood (AD−OD)/OD = 15/100 where AD = (AD−2.4)/2.4 = 15/100 therefore AD = [(15 × 2.4)/100] + 2.4 = 2.76 t.

mangrove stands. For this reason mangrove is too expensive for commercial exploitation.

If we assume that a family has to pay commercial rates for fuelwood this puts the annual cooking fuel bill for a family of six at \$41.4 – \$151.8 at the Suva prices quoted on Table 22. The price in urban Suva for the equivalent in kerosene as cooking fuel is \$96.52 per year at 17.6¢ per litre, allowing 91.4 litres/capita/year for six people. This is the lowest kerosene retail price. Thus, even at prices in urban Suva, where wood is more expensive and kerosene is much cheaper than in rural areas (see Table 14), all wood except mangrove, is competitive with kerosene, even with the use of current inefficient cooking methods. However, because of its high foreign exchange component, the actual cost of kerosene use for Fiji is much higher than the retail price shown.

Continued and expanded utilization of wood for cooking should therefore be considered on economic grounds, particularly where wood is plentiful, and where it replaces kerosene. Fuelwood supplies are generally plentiful, as shown in Frith (1978) and by our study. However, where demand for land will become critical in the near future, other alternatives need investigation.

(2) Wood for Rural Electrification

Johnston's (1977) paper succinctly summarizes the current state of thinking within the Fiji government on utilization of wood wastes for rural electrification. Pertinent points made in this paper are:

- Relative costs of industrial diesel oil to wood in rural areas will be approximately 4.3:1.
- Every 100 ha of pine, cut and replanted on a 15-year cycle, would provide sufficient wood waste to generate over 600 kWh/day of electricity.
- Electrification by a steam-turbine system is probably economically viable but only on a scale that would be too large for village use (200 kW).
- Electrification by wood gas would be possible on a village scale.

Guidelines from a European manufacturer (ROTH), estimate that a wood gas producer will consume 30 kg/h of dried wood to produce a 20 kW output of electricity. If we assume that such wood gas producers for electricity generators were available, potential electricity production from wood presently used by the case study villages is as shown in Table 23.

(3) Wood for Charcoal

Wood charcoal, now produced in very small quantities and still used in some villages for ironing, played a more substantial role in earlier years in Fiji. Figures on commercially sold charcoal obtained by the Central Planning Office from old government files are: 1946, 192 t; 1947, 266 t; and in 1952, 70 t. In the records of the 1945 tests on the Princess Risborough charcoal kiln it was concluded that "rapid deterioration and high initial costs prohibit widespread use."

Charcoal production from old coconut wood is presently being investigated by the Fiji Forestry Department. An erratic supply of charcoal from mangrove wood (*Bruguiera gymnorhiza*) is produced to meet local barbecue needs. However, despite its high energy content, (Richolson and Alston 1977), charcoal yield from each kilogram of

Table 23. Electricity potential of wood presently used in village case studies.

Village	Total daily wood use (kg oven-dry weight)	Generator size in kW	Hours of generation per day
Natia	104.8	10	7
Yaroi	270.8	20	9
Nacamaki	599.3	20	20
Naqelewai	83.1	10	5.6

Table 24. Kitchen vegetable rubbish and animal population in case study areas.

Case study	Population	Total organic rubbish (fresh weight) thrown out per day (kg)	Potential gas[a] (m^3/day)	Pigs	Cattle	Potential gas[b] (m^3/day)	Chickens	Potential gas[b] (m^3/day)	Total (m^3)	Possible use of present potential
Natia	60	19.27	0.11	1		0.05	225	1.35	1.51	2 h lighting for eight bures
Yaroi	241	37.1	0.22	51		3.83	82	0.49	4.54	1 h lighting for village (41 bures)
Nacamaki	321	51.40	0.31	125	—[d]	9.38	66	0.40	10.09	2 h lighting for village (42 bures)
Naqelewai	90	33.77	0.20		—[d]		10	0.06	0.26	Insufficient
Sigatoka farmers										
A	6	2.06	0.01		12[e]	23.22			23.23	Cooking and lighting[d]
B	9	—[c]	—		7[e]	7.25	40	0.24	7.49	Cooking and lighting
C	10	1.24	0.01		2[e]	2.07	3	0.02	2.09	Cooking only
Seaqaqa farmers										
A	3	2.63	0.02						0.02	Insufficient
B	4	—[c]					12	0.07	0.07	Insufficient

[a] Boshoff (1963).
[b] See Appendix 4.
[c] Negligible.
[d] Cattle present but dung cannot be collected, therefore, it is not considered here.
[e] Cattle come home to sleep in a restricted area near the house.
NOTE: Our big pig farm and dairy/beef/pig farms are not included here.

Table 25. Wind measurements at case study areas.

Area	Dates monitored	Maximum average wind speeds (duration) (km/h)	Minimum average wind speeds (duration) (km/h)	Distribution of wind velocities in hours duration					
				10 km/h	10–15 km/h	15–20 km/h	20–25 km/h	25–30 km/h	30 km/h
Natia (Viwa)	31/8–1/9/77	8.1 (1 h)	2.4 (26 h)	All the time (164)	—	—	—	—	—
Vuda Point	18/10–22/10/77	17 (3 h)	4 (18 h)	52.25	8	10	—	—	—
Sigatoka Coast	4/11–10/11/77	37 (2 h)	1 (14.5 h)	91.5	12	6.5	—	3.3	2
Yaroi (Matuku)	5/12–11/12/77	3.3 (6.5 h)	1 (26 h)	All the time (164)	—	—	—	—	—
Nacamaki (Koro)	15/12–19/12/77	20 (2 h)	0.3 (14 h)	89	11.5	7.5	2	—	—

NOTE: For use of wind energy, information on velocity at any given period and the duration of that period is important. Average wind velocity over a year is not as useful.

wood is so low (up to 25% by weight) (Vaganalau 1978) that for energy conservation alone there is no question of charcoal replacing wood in rural homes that are near plentiful fuelwood supplies.

Organic Wastes for Biogas

Measurements of organic waste production show inadequate regular vegetable waste production in all case study sites. Except for the tobacco farmer, all vegetable wastes produced in homes consist of kitchen rubbish. This is tabulated in Table 24. Animals, if kept, are normally unconfined. Dung collection is therefore only possible by hand from the fields. Interestingly, villagers at Yaroi, contrary to general belief, claimed to be willing to collect pig dung by hand to feed a biogas digester.

Fiji now has a total of 16 known biogas digesters of various sizes and designs. All except one are fed pig waste. The exception, only completed in June, 1978, is fed poultry waste (see Survey of Biogas Digesters under Detailed Reports). Results of the survey of biogas digesters show that pig waste-fed digesters at present costs and designs are not suitable for village or small rural community use. This is due primarily to the large number of pigs required (i.e., 100 pigs of average weight, 45.5 kg, for a household of six).

If biogas technology that used vegetable wastes were available at costs that were reasonable for a rural village in Fiji, the possible biogas production from the present daily production of organic wastes would be as shown in Table 24. No village would be capable of producing enough gas for both cooking and lighting. Thus, any attempts to introduce biogas to village communities should consider supplementing the presently available raw materials.

It is apparent that given the present level of development of biogas technology, and given the present situation in rural Fiji, potential biogas use will be necessarily restricted to the wealthier pig, poultry, and dairy farmers.

Results of interviews with rural peoples indicate that individual biogas systems may be more successfully accepted than community systems for villages.

Wind

Wind data for Fiji is scanty, because there are few weather observation stations. The data that have been collected reveal a maximum mean annual average wind speed of only 19.8 km/h, which occurs at two of the stations. The graphs of wind speed variation on the same figures show that wind velocities are usually higher during the second half of the year, June to December.

Attempts were made to obtain some indication of wind velocities at our various case study areas. These are summarized in Table 25. These data cannot be used for any kind of conclusions about wind energy as it is necessary to know the duration of wind speeds at any particular velocity over a number of years. However, the locals at the case study areas informed us that the wind conditions were not unusual and that in some cases stronger winds could be experienced. The exception was at Sigatoka where the farmer claimed that such strong persistent winds (over 30 km/h) were characteristic only of prolonged drought periods.

If wind energy is to be utilized in rural Fiji, much more data must be collected. Information available indicates that mechanical use, such as for pumping, pounding, or polishing, should be preferred to electricity generation.

The smallest case study village was the site of an experimental 2 kW Dunlite wind-driven electricity generator. Unfortunately, this experiment was inconclusive. Without sufficient data from practical trials, cost/kWh of wind power in Fiji cannot yet be determined.

Water

Higher capital input is needed for hydroelectricity generation than for diesel and this has prohibited hydroelectric schemes for rural centres. In 1977, the government started a small village scheme, but it is too early to access this project.

Detailed Reports

This section is divided into four parts and gives the detailed findings on biogas, existing cookers, electricity from autogenerators, and a social assessment of the study populations' aspirations for change.

Survey of Biogas Digesters

This section reports our attempt to assess the present state and the future possibilities of biogas systems in Fiji. We inspected 11 of the total 16 biogas digesters reported to us by the Ministry of Agriculture and Fisheries. There are probably no more than 20 biogas digesters in all of Fiji. The various types of digesters are summarized in Table 26.

Of the six digesters not in use at the time of the survey, four were not completely installed, one was intermittently used for laboratory experiments, and one was temporarily out of use due to a fault in the gas cooker utilizing the biogas.

Aims of the Survey

The survey attempted to achieve the following objectives:

(a) To find the smallest viable size for a pig waste-fed biogas digester;

(b) To identify any technological difficulties associated with running existing digesters; and,

(c) To assess the technological, economic, and social possibilities of biogas generation for use in villages and other rural situations.

Methods

As well as conducting personal interviews, to gauge how each farmer felt about the production and use of biogas, we gave each farmer a questionnaire. No samples of slurry or effluent were taken, as we had neither manpower nor available laboratory facilities to carry out appropriate analysis.

Results

The results of the survey are set out in Table 27. Before reading this table, note should be taken of the following points:

(a) Net running costs are taken as the differences between cost of pig feed and sale of pigs. Labour required daily to clean the

Table 26. Various types of digesters in Fiji.

Size (m^3)	Total	Type	Visited and assessed	Visited not assessed	Not visited not assessed	Not in use
15	1	Neoprene	1	—	—	—
7.5	2	Concrete and steel	2	—	—	—
5.0	5	Concrete and steel	3	2	—	2
5.0	1	Corrugated iron	—	1	—	—
1.5	2	Concrete and steel	2	—	—	—
Unknown	1	All concrete	—	—	1	1
Unknown	2	Neoprene	—	—	2	2
Unknown	1	Unknown	—	—	1	1
Unknown	1	Unknown	—	—	1	—
Total	16		8	3	5	6

Table 27. Working digesters surveyed.

								Capital costs in current prices ($)[b]										
Digester and capacity	Year first used	Home populations	Daily cooking hours (gas use)	Daily light hours (gas use)	Pigs feeding digesters[a]	Water Input (litres)	Estimated daily gas output (m^3)	Digester	Gas cover	Pipes	Labour	Appliances (stove)	Transport	Total less transport	Costs less sale	Main-tenance	Fuel benefit	Net benefit
No. 1 7.5 m^3	1972	9	6.9	—	40	1800	0.3	610	210 (gift)	60	120	22	—	1022	—	20	143	123
No. 2 5 m^3	1975	16	4.5	—	70	2200	0.5	652	297	170	576	120	124	1815	−4260	27	253	226
No. 3 1.5 m^3	1971	5	3.5	0.98	16–20	23	0.2	136	155	66	—	8	—	365	−2448	10	79	69
No. 4 1.5 m^3	1975	6	1.04	—	6–8	18	0.06	222	218	93	—	30	10	563	− 660	6	14	8
No. 5 15 m^3	1977	7	1.7	—	16–20	27	0.2	814	—	30	48	9	—	901	− 719	3	63	59
No. 6 5 m^3	1974	Govt. institution	1	—	100	450	0.8	Total 3020	—	—	980	3	—	4003	Gas is not used regularly			
No. 7 7.5 m^3	1976	Govt. institution	3.6	—	Not available	Not available	Not available	488	158	173	—	18	—	837	Not enough information received			

[a] Based on equivalent adult pig of 45.5 kg.
[b] Costs were provided by the operators and are according to the year specified.

piggery and feed pigs is valued at zero opportunity cost.

(b) Where a farmer only fattens weaners and does not breed his own, purchase of weaners is included with feed costs. Where a farmer breeds his own pigs, the feed costs of boar and sow are taken into account.

(c) Sale of pigs is the price at which pigs are sold to the abbatoir or to individual occasional purchasers.

(d) Therefore, when: net running costs = feed costs − sales is negative, it is ignored, as this means the biogas is an added benefit. If this item is positive, it indicates that the farmer is, in effect, running the piggery to produce his biogas.

(e) Transport costs of materials for the construction of the digester are given in a separate column as they are very sensitive to geographical location.

(f) Maintenance costs for digesters, are given separately. These costs include the price of kerosene for cooking and unleaded petrol (white benzine) for lighting (where applicable) while the digester is being cleaned and reloaded once a year. The average cleaning and reloading period is estimated as 3 weeks to allow biogas production to return to normal levels (farmers claim it is only 1 week). An extra 0.5 weeks is allowed for minor breakdowns such as blockage of gas pipes. Annual costs of black paint and rust guard for the gas holder are also included for those digesters that have steel-gas holders.

(g) All biogas operators still use a commercial fuel as a supplement or an alternative to biogas for cooking. The fuel is kerosene in all cases except the institutions (Digesters 6 and 7), which use diesel-fueled boilers. Therefore, the savings that accrue through the use of biogas are taken to be the cost of the cooking (or lighting) equivalent of the alternative commercial fuel. For example, in the case of Digester 3 (300 gallons/1.5 m^3) the annual fuel saving is taken to be the retail cost of kerosene necessary to cook meals for 5 people in one year and the amount of white benzine required to produce the same hours of lighting as the biogas lamp. (Kerosene retail prices vary even within short distances, 1−5 km; therefore, the average price from the case studies has been used.)

The equivalent volume of both kerosene and white benzine is calculated from data collected from our major survey. From this we estimate a mean 91.396 litres/head/year where a household cooks entirely with kerosene. Similarly we estimate a mean white benzine gas lamp consumption of 48.57 ml/h. White benzine is used here as the alternate fuel for lighting, rather than kerosene, because benzine gas lamps are of similar light intensities to the biogas lamp and are more widely used than the equally bright kerosene Tilley lamp (see Table 6). Taking the mean of the rural shop retail costs from our case studies, we have valued kerosene at 19.3¢/litre expressed in 1977 prices.

Burners

Gas burners in five cases were designed for LP Gas but the owners had widened the gas apertures for use with biogas. All the burners have worked well so far with hot, blue, and soot-free flames. Gas rings vary in size and type, and range in price from $3 to $30 each. Biogas operator No. 5 uses an old kerosene stove with a ring burner to burn his biogas.

Light

Only one operator also uses biogas for lighting. His lamp, installed in the kitchen, came from India, through the Economic and Social Commission for Asia and the Pacific (ESCAP), as a demonstration piece. This lamp burned only for evening meals for an average of 59 min/day.

Farmers' Reactions

Except in one case, all digesters were built by either Mr George Chan of the South Pacific Commission, or the Agriculture Department with Mr Chan's supervision. The one exception was built by the owner to Mr Chan's design specifications.

Table 28. Current and planned use of effluent by the digester operators surveyed.

Operator	Current use of effluent	Planned future use
Digester 1	Pumpkin and citrus fertilizer	Not clear
Digester 2	None	To spray onto pastures
Digester 3	Integrated farming system of algal troughs and fish/duck pond[a]	Bulldoze over the area presently occupied by the integrated farming system to build a bigger piggery
Digester 4	None	None
Digester 5	Occasionally on Dalo patch	Integrated farming system
Digester 6	Fertilizer for cabbage garden	Integrated farming system
Digester 7	Integrated farming system	
Other digesters visited but not assessed		
Tailevu	Chilli/citrus/banana fertilizer	Nothing planned
Koronivia	None	None
Veisari	None	None

[a] Integrated farming system here is that advocated by G. Chan of the South Pacific Commission. The effluent runs through a series of algal ponds, into a fish/duck pond and into a vegetable patch. Algae and fish may be harvested regularly for pig feed.

All farmers with operating digesters were sufficiently satisfied with their installations to plan on either building another one or extending the use of the present one.

Effluent

The effluent, although utilized to some extent, is not put to maximum use (Table 28). It is evident that to the farmers, biogas digesters are primarily for the generation of gas for cooking, lighting, etc. The fertilizer value is a side benefit that has as yet to be fully realized. Sampling of selected field parameters of Fiji's biogas digesters by Solly (1977), shows that digester effluent under present practices, requires further treatment before general use because of insufficient reduction in COD.

Analysis of Results

Piggery Size

Our analysis of annual income and expenditure of seven different pig farms indicated that: (a) these pig farms use commercial feed — as indeed 70% of those surveyed do; (b) small farms purchase weaners from commercial breeders and do not breed their own (only 40% of piggeries surveyed breed all their own weaners); (c) pigs are sold at an average of $1.47/kg; (d) values are all in 1977 prices; and (e) labour costs have been ignored as unskilled labour is plentiful. Transport costs, which are dependent on geographical locations, have also been ignored. Adjustments depending on location can, however, be made for individual farms.

Our analysis shows a break-even point for commercial pig farming at 28 pigs sold per year. However, for a reasonable standard of living where the farmer grows most of his food he should make an annual profit of at least $2000 (a minimum pig production of 4–5 pigs per month or 8–10 pigs every 2 months). This figure was computed from a rough analysis of domestic expenditure of one of the average farmers covered in the case studies. Therefore, this means a minimum piggery size of three concrete pens, each being able to hold 8–10 pigs. Farmer No. 3 has this minimum size piggery and in 1977 he made an estimated annual profit of $2520. He mixed his own feed and produced an average 50.9 kg dressed weight per hog 4 months after weaning.

In 1977 prices the initial capital outlay for a three-pen, concrete piggery was at least $263. To meet the local consumption level of pork in 1977 an additional 160 small three-pen piggeries would have been required.

If all piggeries with 10 or more equivalent adult pigs had been outfitted with a biogas digester, and the biogas used for cooking only, 15 additional piggeries for 1978 would have saved 8225 litres of kerosene importation for that year assuming an average family size of six.

Biogas from Pig Waste

Feed Effect

A small commercial piggery of the above minimum size fitted with a biogas digester, will produce enough gas for an average six-member family's cooking and some lighting needs, provided the pigs are fed on commercial feed (either ready-mixed or mixed by the farmer from fishmeal, meatmeal, coconut meal, and wheat pollard and wheat bran). Table 29 shows approximations of actual gas production from three small piggeries that were surveyed. Of these three, only the digester that uses commercial feed is able to produce the amount of gas expected following estimates provided by the *Energy Primer* (see Appendix 4).

Operating Conditions

Of the digesters known to us, 56% are of the Chan concrete and steel design (Fig. 12). Mr Chan (1975) explained that this particular digester type is "designed for one day's retention in each compartment, and the dilution is ten times the volume of the animal wastes."

Taiganides and Hazen (1966) give varying daily manure productions of a 45.5 kg hog, from 1.3 kg/hog to 3.8 kg/hog. On average their results suggest a mean 2.6 kg/hog. Using Table 4 of Taiganides and Hazen (1966) we estimate 4.55 litres of fresh dung produced by a 45.5 kg hog per day. As Mr Chan's digester is designed for 1-day retention, this suggests a maximum 45.5 kg adult pig number per digester as tabulated in Table 30.

Whether Mr Chan means a 10% dilution in the digester or in the input slurry is not very clear. It appears that he is referring to both components of the system for he envisages only a 1-day retention time. This is rather contrary to other findings. For example, Chung (1973) states that only after 15 days are both the volume and methane composition of biogas at a peak. Work on pig, dairy, and poultry wastes by Gramms et al. (1971) shows that for pig waste, 15-day retention time and 0.24 lb volatile sol-

Table 29. Estimates of gas outputs of the three smallest piggeries surveyed.[a]

Digester and feed type	Type and size (m^3)	Number of equivalent adult pigs (45.5 kg) daily water input[b]	Mean daily use of gas over a 2-week period (h)	State of supply	Mean gas pig/day
No. 3 Commercial feed	Concrete 1.5	10–20 pigs (usually 14) 18–22 litres	3.5 cooking 0.98 lighting	Always excess gas	At least 3.08 ft^3 (0.09 m^3)
No. 4 Milk and cassava	Concrete 1.5	6 pigs 18.2 litres	1.04 cooking	Not enough gas — all used up in 2 days every week	Approximately 2 ft^3 (0.06 m^3)
No. 5 Restaurant left-over	Neoprene 15	16–20 pigs 27 litres	1.7 cooking	All gas used up in 4–7 days (possible leakage)	Approximately 1.2 ft^3 (0.04 m^3)

[a] These estimates were obtained as follows: A 2 in (5.08 cm) gas ring burns 11.5 ft^3 gas/h and one mantle for lighting burns 3 ft^3 (0.08 m^3) gas/h. Thus per pig mean gas produced per day = $(xh_1 + yh_2)/n$, where x = cooking gas vol/h, h_1 = cooking h/day, y = lighting gas vol/h, h_2 = lighting h/day, n = number of adult pigs. No. 3 digester usually has an average of 20–24 animals, which at the time of the survey gave the equivalent of 14 × 45.5 kg adult pigs. No. 4 had six animals of varying weights, which gave an equivalent of 6 × 45.5 kg adult pigs. No. 5 had 4 sows, 1 boar, 6 porkers, and 19 piglets at the time of the survey. We have taken these as equivalent to 14 porkers (in total weight), i.e., 14 × 45.5 kg adult pigs.

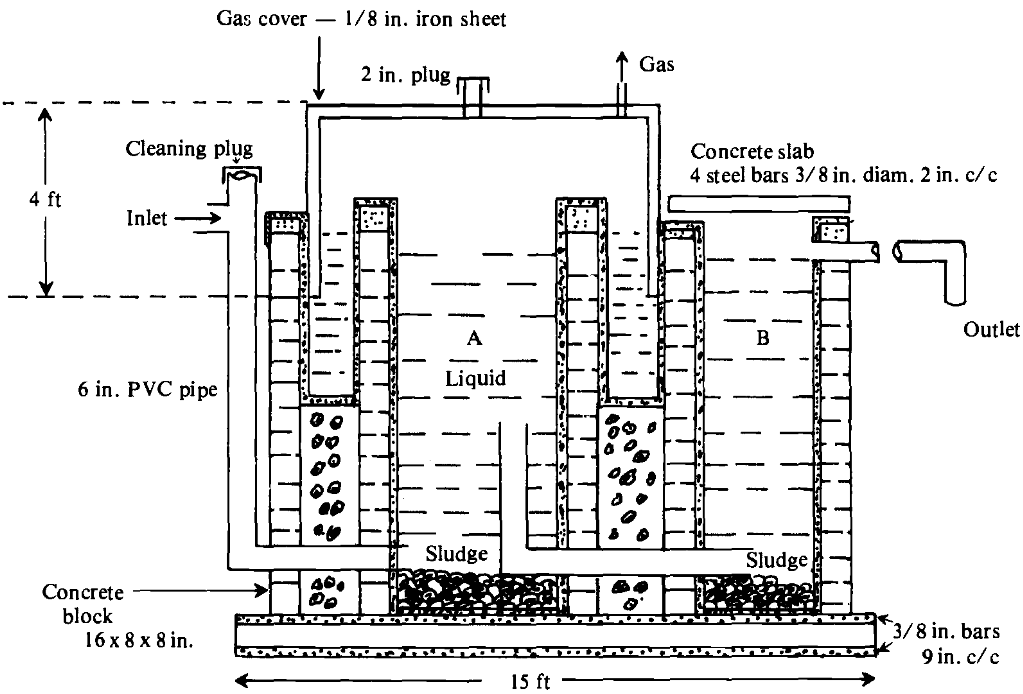


Fig. 12. *A concrete digester with steel gas holder. (A = digester, B = settling tank, 1 ft = 0.3 m, and 1 in. = 2.54 cm.)*

Table 30. Maximum pig number per digester of the Chan design.

Digester size (m^3)	Digester volume (litres)	Maximum daily wet dung input	Number of adult pigs (45.5 kg)	Numbers feeding digester at present
1.5	1365	137	30	16–20
5	4550	455	100	40
7	6825	683	150	70

ids/ft^3/day (3.8 kg vol. sol./m^3/day) loading rate, produce greater biogas volume and better methane composition. Their results show that variation in gas production is more sensitive to retention time than to loading rates.

Solly's (1977) survey of Fiji's digesters showed a 5–15-day retention time, but calculations from the input rates given to us by the biogas operators we surveyed suggested 2–30 days retention.[2]

[2] Retention times were calculated from daily input and digester volume.

Economic Viability of Different Digesters

There are at least three different sizes, four different designs, and three different material types of biogas digesters in Fiji. (Fig. 12 and 13 show the two most common designs.) As far as we know only one attempt has been made so far to assess the financial viability of biogas digesters in Fiji (Solly and Yarrow 1975).

That analysis looked at two concrete digesters of 1.5 m^3 (300 gallon) and 5 m^3 (1000 gallon) sizes and a corrugated iron digester of 5 m^3 size. Benefits were evaluated in terms of their equivalent in

LPGas, and the study concluded, therefore, that the initial capital outlay on all three digesters would be completely recovered within 3 years.

Solly and Yarrow (1975) used no discounting or shadow pricing in their analysis. (Discounting is the conventional procedure for aggregating costs and benefits that occur at different points in time; shadow pricing is the procedure for valuing the real resource cost of inputs and outputs if these are not adequately reflected by the market price.) As kerosene is the usual commercial fuel used for cooking in rural areas, LPGas does not appear to us to be a reasonable choice by which to value the benefits of biogas (LPG will tend to give an unrealistically high value to biogas).

Our benefit/cost analysis is summarized in Appendices 6 and 7 and Tables 31 and 32. The following points were considered in this analysis:

(a) The stream of benefits and costs were taken in real terms discounted to 1977. Three discount rates (5%, 7.5%, 10%) were chosen.

(b) A life of 30 years was estimated for the concrete digesters and a life of 10 years for the metal gas covers (Srivastara and Moulik 1977; Prasad et al. 1974). It was assumed that the farmers would replace the gas covers and continue to use the digesters for the full life expectancy of 30 years.

(c) A life of 30 years for gas pipes and 10 years for all appliances was also estimated.

(d) The benefit/cost analysis is in two parts. The first part (summarized in Appendix 6) assesses the digesters at their present patterns of use. The second part (summarized in Appendix 7) analyzes their performances assuming full loading according to design. Again estimates of gas production at full loading are based on those in *Energy Primer* tabulated in Appendix 4.

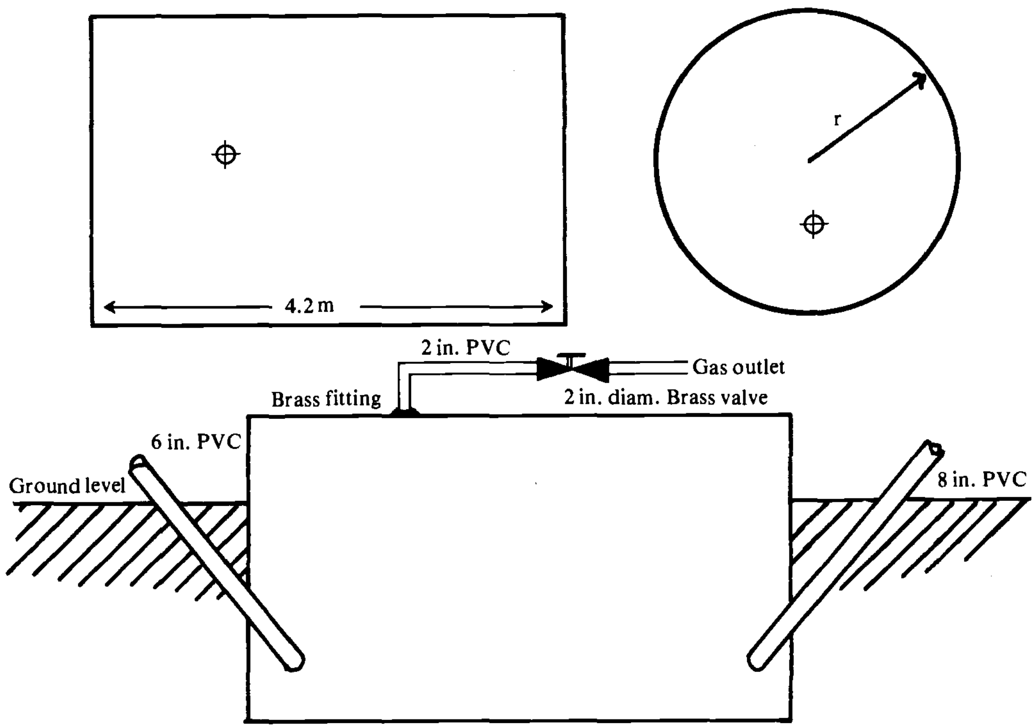


Fig. 13. *Neoprene bag digester (15 m^3). Approximately two-thirds of digester volume is waste plus water, and one-third is gas storage. (One in. = 2.54 cm, and r = 1.75 m.)*

Table 31. Analysis of digesters at present loading and usage (loan repayment periods of digesters at varying rates of interest and capital subsidy).

		Years to repay capital loan for the digesters									
		Digester 1 (7.5 m^3)		Digester 2 (5 m^3)		Digester 3 (1.5 m^3)		Digester 4 (1.5 m^3)		Digester 5 (15 m^3)	
Interest rate (%)	Subsidy rate (%)	Fuel	Fuel and fert.	Fuel	Fuel and fert.	Fuel	Fuel and fert.	Fuel	Fuel and fert.	Fuel	Fuel and fert.
	0	20	17.7	8	7.5	17	15.2	>50	>50	25	21.5
5	25	13	11.7	6	5.3	11.5	10.3	>50	>50	15.5	13.6
	50	8	7	3.8	3.5	6.8	6.3	>50	>50	9.9	8
	0	>60	>60	11.9	10	>60	>60			>60	>60
10	25	30.5	21.1	7.3	6.5	19.7	16.3	All	>60	>60	36
	50	10.4	9.1	4.3	4	8.8	7.8			12.8	10.9

Table 32. Loan repayment periods of existing digesters at varying rates of interest and capital subsidy (assuming full loading of digesters).

			Years to repay capital loan for the digesters							
			Digester 1 (7.5 m^3)		Digester 2 (5 m^3)		Digester 3 and 4 (1.5 m^3)		Digester 5 (15 m^3)	
End uses	Interest rate (%)	Subsidy rate (%)	Fuel	Fuel and fert.	Fuel	Fuel and fert.	Fuel	Fuel and fert.	Fuel	Fuel and fert.
Cooking		0	36	17	36	21	12.5	11	13	5.7
	5	25	19.3	11	20	13.4	8	7.5	5.7	4
		50	11	6.7	11	7.5	5.3	4.6	5.3	2.7
		0	>60	>60	>60	>60	23.5	18	25	7
	10	25	>60	19	>60	34	11	10	7	4.7
		50	17.7	8.5	33.5	10.3	6.5	5.3	6.5	2.9
Cooking and lighting		0	7	6	7.5	6.7	6.7	6	3.7	2.7
	5	25	5	4.2	5.3	4.6	4.8	4.6	2.7	2
		50	3.3	2.8	3.3	3	3.1	3	1.9	1.5
		0	9	7.5	9.5	8.1	8.5	8	4.2	3
	10	25	6	4.8	6.2	5.3	5.7	5.3	3	2.2
		50	3.8	3	3.9	3.4	3.5	3.3	2	1.5
Cooking and refrigeration		0	15	11	16	12			7	4.2
	5	25	10	7.5	11	8	Not possible		5	3.1
		50	6.3	4.8	6.6	5.3			3.3	3.1
		0	<60	17.7	<60	24			9	4.8
	10	25	16	10	17.3	12			6	3.5
		50	8	5.3	8.5	6.5			3.8	3.5
Cooking, lighting, and refrigeration		0	6	5	6	5.3			3	2.4
	5	25	4.3	3.7	4.2	3.9	Not possible		2.3	1.8
		50	2.4	2.3	2.8	2.5			1.6	1.2
		0	7	6	7.5	6.5			3.3	2.6
	10	25	5	4.2	4.8	4.5			2.5	2
		50	2.5	2.3	3	2.9			1.8	1.4

(e) Only the individually owned digesters, which produce gas for domestic use, have been used in the analysis.

(f) Only two interest rates for loan repayment calculations have been chosen. The 5% rate is the Fiji Development Bank government subsidized interest rate of loans to farmers. The 10% rate is the past Fiji Development Bank loan interest rate. The current rate is 9% introduced after these analyses began. The annual loan repayment sum is taken to be the annual net benefit (i.e., annual benefit less annual running and maintenance costs).

(g) It has been assumed that appliances will not be included in the loan sum but will be paid for from other sources of funds available to the farmer as he would purchase them or their equivalents in any case.

(h) All prices are expressed in 1977 equivalents using indices derived from Fiji's Building Materials Prices Index in *Current Economic Statistics*, October, 1977.

(i) All our "shadow prices" are derived from the Central Planning Office input-output tables.

Fertilizer Value

The literature is not conclusive (Sanghi and Doy 1976; Disney 1976) on the net benefits of biogas digester effluent as a fertilizer. Those who argue that organic wastes become more valuable as a fertilizer after anaerobic digestion usually do so on the basis of increased available nitrogen content (Prasad et al. 1974). However, Rudolfs (1928) reports that increased nitrogen percentage after digestion may be attributed to loss in total solids during digestion and increased solubility of nitrogen with time. This implies an important difference in fertilizer value of liquid effluent and dry digested sludge. Snell (1943) points out that much of the original solids is lost in the supernatant and that dry manure solids from digested wastes contain only 2.02% nitrogen expressed as percentage of original solids, compared to 3.62% nitrogen in original solids. Hart's (1963) study suggests no significant change in total nitrogen percentage content. Berger (1976) reports the same for a gobar gas plant effluent.

Accumulated evidence indicates that nitrogen content, although not altering substantially in quantity, is altered in form and is converted largely to soluble ammonium radical (Rudolfs 1928; Hart 1963; Snell 1943; and Gramms et al. 1971; and Hobson and Shaw 1972), which is important as it is then easily available to plants.

The results of the work of Baines (1970) and of Taiganides and Hazen (1966) been used and the benefits of digester effluent have been valued as the difference in its value as fertilizer before and after digestion. This is based on both nitrogen content and effect on crop yield. Baines reports superior yields of potatoes and grass that received digester effluent as compared to those that received balanced NPK and undigested farmyard manure (see Appendix 5 for calculations).

The Analysis

Capital Costs

The farmers provided information on costs incurred for the purchase and installation of the digesters. These figures were checked by consulting the detailed plan of Mr Chan's design and by checking material costs at some local retailers.

Capital costs for the first part of the analysis on the present use of biogas have also been used for the second part of the analysis (assuming full loading and various levels of use). The price of some appliances has been included in the capital costs because the farmer cannot use his biogas unless he has appliances to use it with. They are real expenditures for him. A different set of burners and lamps will have to be acquired to allow for the change from kerosene to biogas. A set of kerosene burners and lamps must still be retained for use when the digester is cleared once a year. An existing kerosene refrigerator can, however, be converted for use with biogas. To include the price of a refrigerator in the capital costs would be justified because so few rural households own refrigerators. The purchase of a refrigerator for use with a biogas system would mean a real cash expenditure for the farmer, however, the benefits of refrigeration are difficult to quantify. Those immediately identifiable include greater variety in food intake resulting in better health, fewer visits to the doctor, and an increase in productivity. Protein consumers are able to increase and regulate their protein intake, which is particularly important for young people who could as a result develop better physically and mentally and, therefore, be able to take advantage of more opportunities for a better life. It has, therefore, been decided to exclude the cost of a refrigerator from the capital costs but refer to it in footnotes under each relevant table. Calculations can therefore be made from the farmer's point of view.

The construction of a biogas digester requires supervision by a semiskilled person. So far this person has been an Agriculture Department extension officer. Therefore, a week's salary for the officer is included in the capital costs. Total discounted capital costs (DC) equal $C_1 + C_2 + C_3$, where: C_1 = initial capital outlay in year 1; C_2 = replacement in year 11 of gas cover and appliances; and C_3 = replacement in year 21 of gas cover and appliances. Both C_2 and C_3 are discounted to year 1.

Subsidy of Capital Costs

Costs information collected from one of the government institutions revealed total expenses at only 73% of the costs associated with an equivalent size digester at one of our farms. This resulted from the purchase of most of the required material from the Fiji Government stores. Through the government's rural housing scheme, building materials are made available to rural peoples from the government stores. Transportation to rural areas is managed by the government.

The argument for bringing biogas digesters under a similar scheme is just as strong as, if not stronger than, that for housing. Unlike housing, biogas digesters are productive. Investment in digesters increases fuel production, which results in foreign exchange savings for the country. Biogas digesters have the potential to lift rural life standards not only in terms of their domestic uses (cooking, lighting, and refrigeration) but also in terms of their agricultural uses (power for water pumps, milking machines, or effluent for fertilizer).

Another government subsidized, rural project is the small, diesel-generated electricity scheme. Government subsidy for this scheme at five-sixths is justified solely on the social benefit of improved lighting conditions. Our analysis of this project shows that the majority of these diesel systems will not be economical. Furthermore, their running costs will continue to increase markedly because they are based on an imported petroleum fuel.

It is not unreasonable, therefore, to suggest that similar arrangements could be devised for biogas digesters using two subsidy rates at 25% and 50% for the digester materials. A 25% subsidy rate is similar to buying materials from government stores, but a 50% subsidy rate would enable many more farmers to acquire digesters.

Benefits

(a) The farmer benefits by (1) being able to produce his own fuel and therefore becoming to some extent, independent of the forces that affect prices and supply of commercial fuels; (2) having a ready supply of fertilizer from the biogas effluent and thus increase his self-sufficiency in crops or even his sale of crops; and (3) by acquiring other unquantifiable benefits such as more varied and probably more nutritious meals from the acquisition of a refrigerator; increased opportunities for economic and social advancement from better health; improved lighting conditions without the constant fire risk incurred through the use of the widespread benzine lamps; cleaner cooking conditions; an almost odourless piggery; and the reward of being self-sufficient in fuel, fertilizer, and most food supplies, with no insect nuisance from exposed raw wastes.

(b) The nation's benefits include the quantifiable amounts of foreign exchange arising from savings made in commercial fuel and fertilizer and the unquantifiable benefits resulting from the reduction in pollution of waterways and the increase in public health. The concern over public health is claimed to be important in China, where human wastes are also widely used.

The literature indicates a relative lack of information on the microbiology of biogas production. The comprehensive review paper by Toerien and Hattingh (1976) reports findings of microbiological works to 1967. These findings show two clear phases in biogas production. The nonmethanogenic first phase involves a wide variety of aerobic, facultative anaerobic, and anaerobic bacteria. Experiments reported in the paper show that filamentous fungi, yeasts, coliforms, and anaerobic bacteria declined rapidly in number particularly after approximately 14 days in the digester. The results suggest that treatment of wastes by anaerobic digestion does serve to eliminate some potentially dangerous microorganisms. When harmful microorganisms are included among those that cannot survive prolonged anaerobic conditions, the health benefit of biogas digestion becomes obvious.

Only fuel and fertilizer have been included in this analysis as benefits not because they are considered to be the most important but because they are the only ones that are quantifiable under the present method of assessment.

The Discounted Net Benefits or Net Present Value

Although continuous discounting may be employed the more usual discrete discounting has been used in this part of our analysis, on the assumption that it will be familiar to both farmers and decision-makers.

A biogas digester takes an average of 5 weeks to build in Fiji. In our calculations, we have allowed 3.5 weeks of every year, including the first year, for nonproduction of biogas to allow for digester cleaning and other contingencies. Digester cleaning and other contingencies are not likely to occur within the first year. Thus, actual biogas production in the first year is 47 weeks (52−5), for every other year it is 48.5 weeks (52−3.5). As the 1.5-week difference is a negligible proportion of the year, we have taken benefits for the first year to be the same as for every other year.

Therefore, with constant annual benefits valued at constant (1977) prices, present value is:

$$PV = B\left(\frac{1-(1+r)^{n}}{r}\right)$$

where B is annual benefits net of annual running costs, r is the rate of discount, and n is the life of the project in years.

If the benefits extend for an infinite time and replaceable parts are allowed for, as they are here, the Net Present Value (NPV) = (Discounted Net Benefits) − (Discounted Capital Costs).

Benefit/Cost Ratio (B/C)

For our purposes we have taken Net Present Value (NPV)/Discounted Capital Costs (DC) to be the benefit/cost ratio, where it should be carefully noted that the denominator (DC) includes *only* the initial and parts replacement capital costs discounted and excludes the discounted annual running costs. The latter is already accounted for in the computation of the numerator (NPV).

Results of Analysis: Part A

Results of the analysis of digesters at present loading and usage are presented in Appendices 6 and 7. According to the Fiji Government economists a reasonable current social discount rate should be about 5% while the presently applied foreign exchange factor is 1.2 (that is, the value of foreign exchange to the Fiji Government is 20% more than is shown in the official rate of exchange). Of the digesters analyzed only two (Digesters 1 and 2) presently give satisfactory returns at 5% discount rate and 1.2 foreign exchange factor (Table 33).

Table 33. Summary net present value (NPV) (F$) of digesters.[a]

Digester (m^3)	Present loading	Full loading	NPV full loading[b]
1 (7.5)	93	−121	3412
2 (5.0)	1625	−511	1455
3 (1.5)	−86	339	1399[c]
4 (1.5)	−1439		
5 (15)	−442	−167	4750

[a] Assuming a 5% discount rate, 1.2 shadow price of foreign exchange, no subsidy from government on capital costs, and fuel savings as the only benefit.

[b] NPV at full loading and optimum use, i.e., for cooking, lighting, and refrigeration.

[c] Cooking and lighting only.

NOTE: For the values we have assumed that gas produced is used only for cooking when digesters are fully loaded.

Although the capital costs of Digester 2 are not very different from Digester 1, the returns are better for Digester 2 because it serves a larger family (16 members). The gas is more fully utilized. Similarly, Digesters 3 and 4 are of equal capacity, but Digester 3 gives better returns because it is better loaded and more fully utilized.

It should be noted that capital costs of alternative waste treatment plants, such as septic tanks, should be subtracted from the biogas digester capital costs. However, we decided against this procedure as Fiji does not as yet have a definite policy on waste treatment methods for intensive animal farms. Therefore, farmers are not obliged to install any kind of treatment plant.

Overall, the analysis results definitely show disappointing returns on all but one of the existing digesters. This is largely due to one or more of the following: (a) underloading and, therefore, underproduction of biogas fuel; (b) underutilization of the biogas that is produced due to an inadequate number of appliances mounted at the installation of the biogas system; and (c) underutilization or nonutilization of effluent as fertilizer. However, it is important to note that the prices of fuel in Fiji, at both the imported (c.i.f.) and retail price, have increased at a higher rate than the overall consumer price index since early 1974 when the crude petroleum price has not risen in real terms. If this trend continues, the benefits of biogas are definitely underestimated here. It is most likely, therefore, that for the reason already mentioned the NPV will be much higher for all biogas digesters analyzed here.

This point is illustrated by estimating the NPV of all five digesters if it is assumed that fuel price increases are greater than the inflation rate and using only a 5% discount rate and a 1.2 foreign exchange shadow price factor. The results, shown in Table 34 show a marked improvement over those NPV derived on the assumption that fuel price increases equal the inflation rate.

Table 34. Net present value (NPV) and benefit/cost ratio (B/C) of Digesters 1−5 at 5% discount rate, 1.2 foreign exchange shadow price factor, and present levels of use.[a]

	$(\alpha\text{-r}) = 2\%$[b]		$(\alpha\text{-r}) = 4\%$		$(\alpha\text{-r}) = 8\%$	
Digesters	NPV	B/C	NPV	B/C	NPV	B/C
1	4607	2.0	7635	3.3	19312	8.3
2	9564	3.5	15109	5.5	35833	13.0
3.	2586	1.6	4406	2.8	11426	7.3
4	−934	−0.6	−654	−0.4	426	0.3
5	−273	−0.3	−88	−0.1	97	0.1

[a] The results here were computed assuming a rate of increase in fuel prices (α) higher than inflation rate (r) and assuming continuous discounting. The extent that fuel price rises exceed the inflation rate ($\alpha - r$). NPV = $[\{1\text{-}e^{(\alpha\text{-}r)T}\}\ \{\bar{b}/(\alpha\text{-}r)\}]-\bar{C}$, where α = rate of increase of fuel price, r = rate of discount, T = life of digester in years, $\bar{b}$ = net annual benefit, and $\bar{C}$ = discounted capital costs. B/C = NPV/$\bar{C}$.

[b] The extent that the increase in fuel price exceeds the inflation rate ($\alpha - r$).

Results of Analysis: Part B

Our analysis of the situation in which biogas provides cooking and lighting for a family of six shows that in every case the benefit/cost ratio and the internal rate of return (B/C = O) is much better if the effluent is also used as fertilizer.

Although the initial capital outlay is much lower for the 15 m^3 neoprene bag digester, its benefit/cost ratio is not significantly better than the more expensive smaller-capacity concrete digesters. This is largely because we have assumed a life of 10 years for the neoprene bag. The lack of advantage is particularly evident when only the fuel benefit is considered.

The results of both parts of the analysis indicate that digester sizes should be carefully tailored to the end-use demand of biogas to obtain optimum returns on investment. For example, if the biogas is to be used for cooking only, the smallest digester (1.5 m^3) appears to be the most appropriate for a family of six. Cooking for a much larger household (15–20 people) will of course require a larger digester. The digester must, however, be utilized to its maximum design capacity (see Table 30). If cooking and lighting are the required end uses of biogas, either a 5 m^3 concrete digester or the 15 m^3 neoprene bag show better returns. At 1.2 foreign exchange shadow price factor, 7.5% discount rate and no subsidy, the benefit/cost ratios for the two (considering fuel only as benefits) are 1.06 and 1.17 respectively. (When refrigeration is included with cooking and lighting, the three large digesters give comparable returns.)

If biogas is utilized for other than domestic end uses, such as water pumping, the two larger digesters (7.5 m^3 and 15 m^3) should of course be installed. We have not, however, gone beyond strictly domestic use in our analysis.

The problem of excess pig dung will inevitably arise where large piggeries cannot make reasonable use of the total potential biogas output. Some means of waste treatment still has to be found. In such cases the composting of wastes (pig dung plus other farm wastes) around the digester to provide a low level of heating would add considerably to the efficient functioning of the digester. In addition, composting provides another acceptable means of waste treatment and a source of fertilizer. This practice would of course involve some modification of present digester designs.

Better economic returns with subsidized capital suggest the advantage of government assistance on digester materials. This can be achieved through the distribution of digester materials by government stores rather than commercial firms. The effect as explained earlier will be similar to the 25% subsidy level. If the farmer borrows capital costs, loan repayment periods are better at 50% subsidy. These results support arguments presented earlier for some means of government aid for digester construction.

Where the discounted net benefits look reasonable (i.e., in part (b) of our analysis where cooking and lighting are the end uses) they could be bettered if the capital costs were lowered. The initial capital costs for the digesters are high by Fiji standards (see Table 27). Experimentation with local materials to cut costs can be fruitful. China and Nepal, for example, have attempted such capital cost savings.

Discussion

Fiji by the end of 1977, had 6–7 years of experience in biogas production from anaerobic digestion of pig waste. There has been much discussion, and many different viewpoints have been offered, concerning the viability of the system in Fiji. As Solly and Yarrow (1975) point out, biogas digesters in Fiji are used primarily as a means of waste treatment for intensive pig units. Where they have an advantage over other possible waste treatment methods is in the production of methane gas for fuel.

As Fiji's rural population increases, and demands on waterways for washing, bathing, and fishing increase, pollution from pig units and cowsheds will become more obvious. Therefore, there will be greater pressure to enforce relevant legislation. Pig and dairy farmers will have to find ways of treating animal wastes. Some of these ways could include open oxidation ponds, septic tanks, or biogas digesters.

A comprehensive review of the current state of biogas technology by Leo Pyle (1978) points out that biogas technology is still underdeveloped. There is ample room for improvement not only in engineering designs but also in knowledge of the microbiological process involved. According to Mr Chan his design is probably inefficient in fluid flow. Improvement in design could be directed at greater flow efficiency, a higher loading rate, and longer retention time. Further improvement is also possible in the design of cookers, lamps, and other biogas end-use apparatus.

At their present early stage of development biogas digesters cannot be compared to the highly developed, and therefore more efficient, technologies such as diesel electricity generation. However, interest in biogas digesters has only recently gathered momentum in most countries, and the fact that interest is growing indicates greater opportunities for technological advance. The quantifiable benefits of present systems under improved practices are satisfactory (see Appendix 7) and the unquantifiable benefits are numerous therefore the argument for a positive policy toward the systematic introduction of biogas digesters is strong. Installations, however, must be confined to commercial animal farms because initial capital costs and animal population requirements for the present system are prohibitive for any other rural community groups.

Promotion Channels

Biogas plants are the responsibility of the Agriculture Department piggery section. When this report was prepared the uncompleted digesters were, for the most part, still unfinished; the large neoprene digester was not functioning due to a leak that had not been attended to for up to 2 months, and a demonstration gas light intended for Digester 4 had still not been installed. These delays in completion, in delivery of end-use appliances, and in follow-up repair services do not aid good promotion. Discussions with the Agriculture Department pig section show no clear guidelines of responsibility within that department for the promotion of biogas. Furthermore, staff shortages necessarily divert the attention of the few remaining staff to the section's main function of pig production. These difficulties suggest a more positive administrative approach. The setting up of a responsible body or unit separate from the pig section of the Agriculture Department seems to be the obvious solution.

Villages and Farmers without Pigs

The outfitting of piggeries with digesters will not make a substantial impact on our overall rural energy consumption, but it appears to be a step worth taking in view of the high foreign exchange content of present energy sources and Fiji's heavy dependence on imports in general and petroleum in particular. Furthermore, as Table 34 illustrates, the continuing faster rate of fuel price increase over inflation rate will improve biogas digester returns markedly. There are added social benefits in pollution control and greater self-sufficiency in energy. Although only the better-off, rural pig farmers will benefit by using present digester designs, the example of energy self-sufficiency that they set is important. Any later introduction of biogas generation using different inputs and perhaps cheaper, more efficient designs should then be more readily accepted by the rural population.

Work is continuing throughout most of the world to explore the extensive use of vegetable wastes, fortified with animal wastes, for biogas production. Vegetable matter investigated or used so far includes elephant grass (Boshoff 1963a), cassava peelings (Tropical Products Institute), banana peelings (Laura and Indnani 1971), fresh legume leaves (Nelson et al. 1939), nonlegume leaves and paper (fitter paper), and a variety of flour types (corn stalks, wheat straw, and flax straw).

Algae and water hyacinth have been used as components of integrated farming systems that have worked well in Southeast Asian countries (Eusebio 1975; Obias 1975; Chung 1973). The attempt in Fiji is still too new to assess. However, the lessons of the floundered Olubus village project should be heeded if an integrated farming system is ever suggested for Fijian villages (Cato 1976). The management skills required for such a system may be too much to ask of the villagers without gradual introduction to the system over many years.

It has been suggested that batch digesters may be more suitable for certain situations such as those in rural Fiji where continuous feeding of input may pose a difficult management problem. In village situations particularly a once-a-month or once every 3 months effort will be easier to maintain than a daily effort. If labour costs are incurred the costs of running a continuous system have been estimated to exceed by 33% labour costs of a batch system (Boshoff 1963a). As these costs are based on labour time required, the estimate should also be true for Fiji. Observations made at the study villages indicate that the organization necessary to run community batch digesters will not be difficult.

Recommendations

The results of our investigations, the analysis of those results, and the reported experience of other countries such as China and India, lead to the following recommendations for Fiji:

- As existing rural biogas digester designs in Fiji and overseas still leave much room for improvement, an appropriate body or institution should be allocated by Government to take on the task of developing digester designs and monitoring their field performances to increase efficiency in gas production and reduce costs.

- Such a body or institution as recommended above could promote installation of biogas digesters and relieve the Agriculture Department piggery section of this extra task. Such a body should also disseminate appropriate information and develop relevant skills for good operating practices.

- Because capital costs of present designs are high investigations should be encouraged to find inexpensive local materials and appropriate simple digester designs. The body or institution in charge of design could also be involved in such investigations.

- As existing designs in Fiji do not achieve adequate public health benefits, because they do not allow long enough retention time to reduce coliform counts to acceptable levels, the development of designs to either increase retention time or allow effluent to be recycled should be encouraged. Again a body or institution as previously recommended could be responsible for such developments.

- Farmers using existing digesters should be encouraged to utilize them up to full capacity. This can be achieved by adding more pigs to the piggery for digester types 3, 4, and 5 and by adding lighting to biogas end use in all cases.

- Any commercial piggeries of at least 30 pigs should be encouraged to install digesters for both cooking and lighting.

- The government should either provide materials at government supply cost or subsidize digester materials by some other means so that the majority of pig farmers will be encouraged to install digesters.

- Any digesters built should be carefully tailored in capacity to actual end use planned. Where there will be excess pig dung, this should, if possible, be composted around the digester to increase gas production. Future designs should allow for such situations.

- Because animal populations in villages and small farms are insufficient to meet fuel demands economically (see Table 24) the planning of biogas use for such situations should await more suitable findings of current overseas investigations.

Comparative Tests of Selected Cookers for Rural and Semirural Areas

This section reports on a joint project to test a range of cookers and to identify inexpensive cooking devices suitable for rural use.[3]

Introduction

For our purposes, rural and semirural (or periurban) areas are those that come under the administration of local rural authorities, but urban areas are those within the domain of municipal authorities of cities or townships. In a large majority of households in rural and semirural areas of Fiji wood burned in an open fireplace is still the major fuel for cooking. Observations, however, indicate a definite swing from firewood to commercial fuels. This trend is expected to continue as family income increases, firewood supplies dwindle, and the proximity of firewood stands decreases. Kerosene is the usual supplement for firewood although we did find two homes at Nacamaki, Koro, with gas stoves, utilizing bottled gas (LPG).

Fig. 14 shows the marked tendency to switch to kerosene for cooking as family income increases in rural homes. It should be emphasized, however, that for most of these homes, firewood is still the major cooking fuel. The switch away from fuelwood as income increases follows a well-known worldwide trend as shown in Fig. 15. It should be questioned whether Fiji can afford to continue to accommodate this trend as import bills for commercial fuels, particularly petroleum products, increase rapidly. Table 35 shows the trend in kerosene consumption in Fiji over the last 10 years and its foreign exchange costs. It is interesting to note that 1975, the year of maximum increase in retail price of kerosene, was also the year of maximum increase in consumption of kerosene. Obviously kerosene is an essential item and at least in the short term, the demand is little affected by price rises.

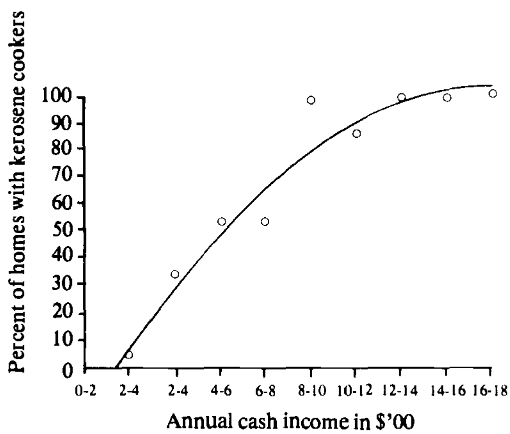


Fig. 14. *Relationship between possession of kerosene cookers and annual cash income.*

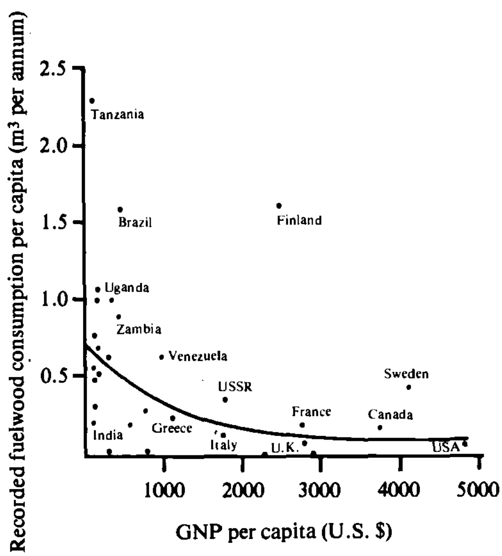


Fig. 15. *Relationship between fuelwood consumption and GNP for selected countries.*

[3] This part of the study was carried out with the collaboration of a number of other institutions. In addition to the supervision and experimenters supplied by the Centre for Advanced Studies in Development, cooking devices and facilities were supplied by the University of the South Pacific's Home Economics Department, a form of "Ghanaian" oven was supplied by the South Pacific Commission Community Leadership Training Centre, and coconut wood charcoal, mangrove wood, and the charcoal stoves were supplied by the Fiji Forestry Department.

Table 35. Fiji's kerosene consumption, and import prices for 1968–1977.[a]

Year	Kerosene consumption (million gallons)[b]	CIF price ($'000)	CIF price (F$/imperial gallon)
1968	2.83	183.95	0.065
1969	3.08	394.24	0.128
1970	3.42	441.18	0.129
1971	3.90	538.20	0.138
1972	4.35	595.95	0.137
1973	4.53	792.75	0.175
1974	4.18	1,504.80	0.360
1975	4.77	1,946.16	0.408
1976	4.98	2,300.76	0.462
1977	5.00	2,675.00	0.535

[a] Information for this table was obtained from the Fiji Government Central Planning Office.
[b] One imperial gallon equals 4.55 litres.
NOTE: Kerosene consumption is in actual sales for the year — from major distributors.

With limited and seasonally fluctuating foreign reserves Fiji needs to encourage self-sufficiency in fuels — even for the humble rural cooking place. Local fuels such as wood and charcoal need to be explored and exploited.[4]

Open fireplaces, at present, so common, do not only pose a fire hazard but also affect health. Our interviews, as summarized in Table 13, indicate the extent of smoke nuisance according to rural women. An average of 78% of all those interviewed complained of eye irritation by smoke.

Medical authorities agree that smoke from wood fires does act as an irritant that will aggravate any eye disease particularly in the old. Table 36 summarizes reported trachoma cases in Fiji since 1971. A survey of one town by the Medical Department, however, showed actual incidence of trachoma to be much higher in Fijians (30% of Fijians surveyed) than in Indians (16% of Indians surveyed). Similarly, smoke will act as an irritant when breathed in through the respiratory tracts. Reported incidents of respiratory complaints that may be aggravated by smoke are shown in Table 37. A medical officer attempted to explain the higher incidence of other pneumonia in Fijians by the fact that Fijians often sleep in crowded conditions, and in some areas they sleep in the same room in which they cook. Where there are old people, or where it is cold, or where mosquitoes abound, such as at Oneata in the Lau group, fires are kept going all night in the sleeping quarters.

It appears that the public health authorities have been concerned and made some attempt to save rural women from overexposure to smoky fires. Nacamaki women informed us that public health authorities advised them to raise their open fireplaces 60–90 cm off the ground and to have broad chimneys over them to vent most of the smoke away. Such fireplaces, known in Fiji as Indian fireplaces, were found both at Yaroi and at Nacamaki. They appear to be an improvement over the traditional ground fireplace. We noted, however, that the traditional open fireplace was used for drying clothes, crop planting material, and firewood, but this new raised fireplace was not. In the traditional village kitchen, a wooden rack is usually built high (1.82–2 m) above the ground fireplace. This would hold firewood and other items to dry over the fire. The broad chimney, brought low over the Indian fireplace, precludes construction of such a drying rack.

The Tests

Purpose

The tests were conducted as part of an attempt to identify cheap cooking devices suitable for rural areas. Such devices should be able to be assembled locally and should utilize local fuel sources efficiently. They may become substitutes for kerosene cookers and improvements over open fires.

Although smokeless wood stoves might be attractive for areas with plentiful supplies of wood, charcoal cookers could be an answer for the periurban dweller and the rural dweller in localities that have diminished firewood supplies, because char-

[4] At the time this report was written the foreign reserves were $100–$125 million or approximately $167–$208 per capita. This is equivalent to 4–5 months imports.

Table 36. Reported incidence of trachoma in Fiji by race and sex (1971–1977).

Year	Urban	Rural	Total	Fijian	Indian	Others	Male	Female
1971	80	216	296	191	59	46	179	117
1972	61	81	142	89	31	22	76	66
1973	21	79	100	72	17	11	54	46
1974	41	59	100	75	17	8	54	46
1975	77	162	239	114	47	78	116	123
1976	16	103	119	27	79	13	64	55
1977	49	246	295	132	157	6	143	152

Source: Medical Statistics Office, Suva.

coal is easier to transport and store than wood. Charcoal may be an alternative to kerosene.

Aims

The tests were aimed at investigating: (1) the thermal efficiency of charcoal cookers compared to the two most common kerosene cookers. (Hong Kong round wick and Swedish primus, No. 1); (2) the thermal efficiency of a smokeless wood stove compared to an open wood fire; (3) the thermal efficiency of charcoal cookers compared to smokeless wood stoves; and, (4) the efficiency and merits of introducing charcoal stoves and smokeless wood stoves to rural and semirural homes.[5]

Equipment

(a) Cookers: kerosene, Hong Kong wick (Fig. 7); Swedish No. 1, (Fig. 8). Charcoal, Forestry Department model (Fig. 9). Wood, open fire (Fig. 6); Indian chula stove (Fig. 5a and 16); modified Ghanaian stove (Fig. 10a and 17).

(b) Oven: Bombay pot over Hong Kong round wick stove, Bombay pot over Swedish primus stove. Charcoal, Forestry Department model (Fig. 9b). Wood, Bombay pot over open fire, Bombay pot over Indian chula (Fig. 5b); Ghanaian oven modified (Fig. 10b).

[5] The Indian chula stove has already been introduced on a limited scale in Fiji. It is not a true smokeless stove, but it allows smoke-free cooking conditions by venting the smoke away. It is not noted for durability and many have been known to crack within 3 years.

Table 37. Reported incidence of common chest complaints in Fiji (1973–1976).

Year	Fijian (%)	Indian (%)	Others (%)	Total
Bronchitis/Asthma				
1973	427 (42.15)	520 (51.53)	66 (6.52)	1013
1974	514 (43.93)	594 (50.77)	62 (5.30)	1170
1975	562 (46.29)	597 (49.18)	55 (4.53)	1214
1976	549 (44.89)	579 (47.34)	95 (7.77)	1223
Total	2052 (44.42)	2290 (49.57)	278 (6.01)	4620
Other pneumonia				
1973	1289 (67.42)	478 (25.0)	145 (7.58)	1912
1974	1315 (74.21)	332 (18.74)	125 (7.05)	1772
1975	1359 (68.81)	477 (24.15)	139 (7.04)	1975
1976	1555 (69.86)	525 (23.58)	146 (6.56)	2226
Total	5518 (69.98)	1812 (22.98)	555 (7.04)	7885

Source: Medical Statistics Office, Suva.

Method

All but the modified Ghanaian stove are located at the University's Home Economics Department. Five senior economics students cooked each dish at the same time over the five cookers on campus. All ingredients were carefully weighed over Harvard scientific double-pan beam balances so that the quantities would not vary. When a Salter kitchen spring balance had to be used it was checked regularly for accuracy.

Wood and charcoal were weighed with an Avery single-pan beam balance of 15 kg capacity. A sample of the wood and charcoal was taken for moisture content determination. All wood used was *Bruguiera gymnorhiza* (commonly known as dogo) and was supplied by the Forestry Department. All charcoal used was from coconut wood, which was also supplied by the Forestry Department. The only noncoconut wood charcoal was that used over the makeshift Bombay pot oven (shown in Fig. 5b), coconut shell charcoal was used for this.

Table 38. Common recipes of Fiji's main cultural groups.

Fijian		Indian (1)		Indian (2)		Chinese (1)		Chinese (2)	
Dishes cooked over burners[a]									
Cassava	200 g	Rice	381 g	Flour	400 g	Rice	390 g	Chicken	1000 g
Fish	300 g	Potatoes	305 g	Fish	110 g	Meat	489 g		+ 1100 g
Leafy vegetables	276 g	Onions	28 g	Potatoes	250 g	Carrots	270 g	Beef	400 g
Salt	5 g	Garlic	6 g	Beans	220 g	Beans	220 g	Carrots	300 g
Coconut cream	325 g	Curry powder	18 g	Garlic	10 g	Ginger	28 g	Beans	230 g
Water (for cassava)	400 ml	Cooking oil	28 g	Onions	20 g	Soy sauce	45 ml	Cabbage	232 g
		Fish	110 g	Cooking oil	20 ml	Cooking oil	30 ml	Garlic	10 g
Water (for tea)	1950 ml	Water (for rice)	970 ml	Butter	60 g	Water (for rice)	60 ml	Ginger	10 g
		Water (for tea)	1950 ml	Water (for roti)	160 ml	Water (for tea)	1950 ml	Onions	60 g
		Water (for curry)	140 ml	Water (for curry)	100 ml			Oil	90 ml
				Water (tea)	300 ml			Soy sauce	45 ml
Dish names									
Cassava, fish in lolo and tea		Rice, fish curry, and tea		Roti, fish curry, and tea		Rice and beef chop suey		Pot roast, chicken, and beef chop suey	
Dishes cooked in ovens									
Plain scones		*Banana cake*							
Flour	400 g	Flour	400 g						
Baking powder	20 g	Sugar	120 g						
Butter	30 g	Butter	100 g						
Salt	2.5 g	Baking powder	10 g						
Milk	300 ml	Baking soda	5 g						
		Milk	85 ml						
		Bananas	100 g						

[a] Each of these dishes constitutes a meal for four people.

Immediately after each meal was cooked, the firewood was extinguished with ash, cooled, and weighed. Charcoal was doused with water, air dried to constant weight, and the final weight noted. Each dish except Chinese meal (1), was cooked twice by the five experimenters. In addition, one experimenter repeated the experiments using all six cookers and ovens. This was to eliminate, as far as possible, differences due to different experimenters. The results were not significantly different from the others.

The Ghanaian stove had to be tested on different days from the others as it is situated at the South Pacific Commission Centre — approximately one mile from the campus. Unfortunately, this stove was not well sheltered, and in two out of the four days when it was tested it had been soaked by heavy rains the previous night.

The use of a Bombay pot over an open fire or over a kerosene cooker to serve as a makeshift oven is common practice in semirural and rural homes and, therefore, these pots were used in our tests for baking. A piece of flat iron is placed between the bottom of the pot and the fire, and another is placed on top. Once the food is placed in the oven, hot charcoal from coconut shells is placed on the top iron plate. The quantity of fuel used, time taken for the cooker to warm up, and actual cooking time, were recorded in each case.

During the tests, kitchen atmospheric temperatures ranged from 25°C to 35°C. Humidity ranged from 41% to 88% with a mean of 71%. Charcoal moisture contents fluctuated appreciably with wide fluctuations in humidity, varying from 12% moisture content at lowest humidity to 81% at 88% humidity and 125% after several days in the rain.

Materials

Cookers were tested by cooking common recipes of Fiji's main cultural groups: Ingredients for these are tabulated in Table 38.

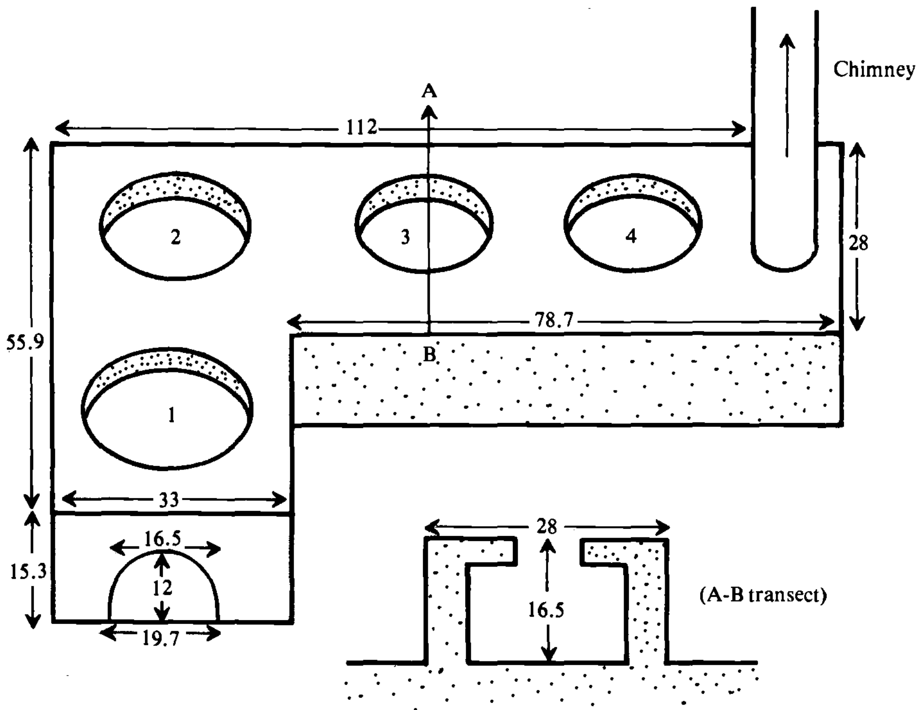
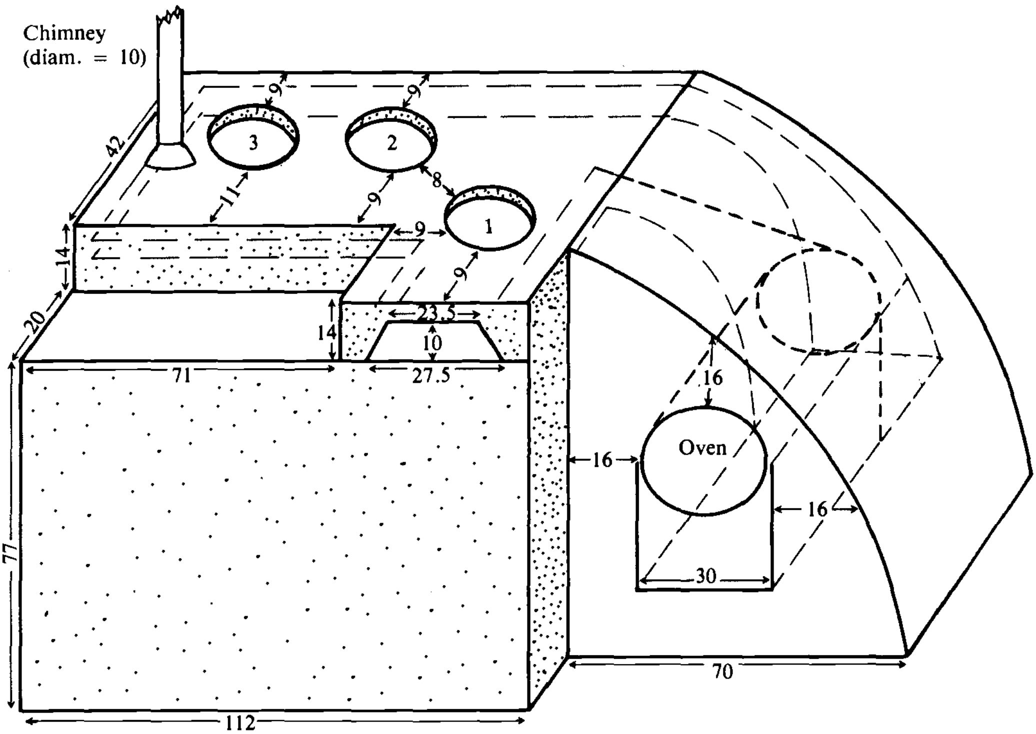


Fig. 16. *Diagram of the Indian chula wood stove at the University of the South Pacific. (The holes for pots are numbered 1 –4 and all dimensions are in cm.)*



Pot holes	Outer diameter	Inner diameter	Concrete wall thickness
1	23	21	5
2	23.5	21	5
3	20	17.5	5

Fig. 17. *Diagram of a modified Ghanaian stove. The oven is a disgarded 18.2 litre oil drum. (Dimensions are in cm.)*

Results

The results of these tests are summarized in Tables 39 and 40. Two lots of firewood were used. These had moisture contents of 43.38%. and 26.58%, where percentage moisture content = ((original weight − oven-dry weight)/oven-dry weight) 100.

Calorific value for kerosene is taken to be 10.905 kcal/g. This figure was obtained from Mobil Oil Co. Calorific value for dogo wood is taken to be 4.87 kcal/g oven-dry weight[6] and the value for coconut wood charcoal as 7.05 kcal/g as reported by Richolson and Alston (1977).

[6] Determined in a bomb calorimeter by C. Wright, Chemistry Laboratory, University of the South Pacific.

We have devised an efficiency index for each of the two sets of results and have used the best regulated burner/oven as a standard in each case. For example, the open fire or the makeshift Bombay pot oven are subject to wind effects and, therefore, cannot be used as standard. Our standards are the Ghanaian oven for baking and the Swedish primus for other cooking. Standard thermal efficiency tests for the appliances are reported in Table 41.

Discussion

If innovation is contemplated for cooking devices in rural and semirural areas, obvious factors that should be considered include the following:

(1) Is the device as cheap or cheaper than those presently available?

Table 39. Fuel consumption and cooking times

	Fijian meal					Indian meal (1)					Indian meal (2)				
			Fuel					Fuel					Fuel		
Cooker type	WT (min)	CT (min)	Amt	kcal	EI	WT (min)	CT (min)	Amt	kcal	EI	WT (min)	CT (min)	Amt	kcal	EI
Kerosene															
Hong Kong wick	3	56	323 ml	2884.8	0.29	3	52	164 ml	1464.7	0.57	7 + 7(R)	49	220 ml	1964.90	0.30
Swedish primus stove	5	53	95 ml	848.5	1	5	52	93 ml	830.6	1	5 + 7(R)	58	67 ml	598.4	1
Charcoal															
Forestry model 1 cooker	10	53	646 g(AD) 450 g(OD)	3172.5	1.77	10	60	553 g(AD) 474 g(OD)	3341.7	0.25	10 + 10(R)	55	530 g(AD) 444 g(OD)	3130.2	0.19
Wood															
Open fire	5	58	1588 g(AD) 1159 g(OD)	5644.3	0.15	5	56	1639 g(AD) 1196 g(OD)	5824.5	0.14	7 + 20(R)	43	1213 g(AD) 885 g(OD)	4310.0	0.14
Indian chula	5	85	2351 g(AD) 1716 g(OD)	8356.9	0.10	5	82	2863 g(AD) 2089 g(OD)	10173.4	0.08	5 + 15(R)	75	2350 g(AD) 1716 g(OD)	8356.9	0.07
Modified Ghanaian	5	70	1480 g(AD) 1028 g(OD)	5006.4	0.17	5	62	1763 g(AD) 1225 g(OD)	5965.8	0.14	11 + 24(R)	53	1372 g(AD) 954 g(OD)	4646.0	0.13

[a] WT = warming up times, CT = cooking time, R = roti grill warming up time, AD = air dry, OD = oven dry, and EI = efficiency index = calories expended by Swedish primus/calories expended by cooker. We have not used cooking time as a basis for comparison, because some cookers can hold two or three pots simultaneously but others cannot, and this would give an unfair basis for comparison. In addition, a slow warm cooker will cook just as well as a fast hot cooker.

(2) Will running costs compare favourably?

(3) Is it durable?

(4) Can it be locally constructed in large numbers?

(5) Will it be easily assimilated into the local way of life?

(6) Is it easy to use and maintain?

(7) Does it present any health or fire hazards?

Woodburners

Of the two wood burners tested, the Indian chula is already well known in Fiji. An official from the Ministry for Rural Development reported that a trial introduction of these stoves to a whole village showed their average functioning age to be approximately 3 years. The concrete body cracks badly after continuous use. The villagers, were unable to replace the stoves easily and reverted to previous devices.

Nevertheless, the Indian chula burner continues to spread into isolated homes throughout the group. We found one of these burners at the village of Yaroi, Matuku. The owners complained that the stove burned too much wood and cracked easily. This particular one was 4 years old. The cracks were mainly around the pot holes and were patched with sheet metal pieces. It burned an average of 1.28 kg of wood (oven-dry weight) per head, per day, while the mean of the open fireplaces in the same village was 1.57 kg wood (oven-dry weight) per head, per day. This burner appears to be more efficient at wood utilization than most of the village open fires. Our test results, however, showed the Indian Chula stove to be consistently less efficient than the open fireplace. The difference in the functioning of the two stoves can probably be attributed to differences in structural dimensions. Information from the South Pacific Commission community field workers indicates that the design is modifed in the village to increase efficiency. Some widely adopted modifications are to make a more spacious fireplace and to narrow the smoke channel. Apart from increased burning efficiency, these wood stoves offer the additional advantage of smoke-free cooking, which should contribute to better health conditions.

The modified Ghanaian cooker is of the same basic design as the Indian chula, but it has an oven attached. The model tested is a modification of the design in *Appropriate Technology*, London, Intermediate Technology Publications Ltd. A stove like this was constructed in 1977 for trial in Dravo (a village near Suva). So far the owners have been delighted with its perforfor different types of cookers.[a]

Cooker type	WT (min)	CT (min)	Chinese meal (1) Fuel Amt	kcal	EI	WT (min)	CT (min)	Chinese meal (2) Fuel Amt	kcal	EI	Efficiency index Total	Mean
Kerosene												
Hong Kong												
Wick	3	57	140 ml	1250.4	0.96	3	144	185 ml	1652.3	0.81	2.93	0.59
Swedish Primus												
stove	5	52	135 ml	1205.7	1	5	125	150 ml	1339.7	1	5	1
Charcoal												
Forestry Model			600 g(AD)					420 g(AD)				
I cooker	10	65	510 g(OD)	3595.5	0.34	15	50	334 g(OD)	2354.7	0.57	1.62	0.32
Wood												
Open Fire	3	70	1300 g(AD)	4621.6	0.03	5	25	895 g(AD)	3180.1	0.42	0.88	0.18
			949 g(OD)					653 g(OD)				
Indian	10	71	2750 g(AD)	9779.0	0.12	5	95	4290 g(AD)	15252.8	0.09	0.46	0.09
Chula			2008 g(OD)					3132 g(OD)				
Modified	3	78	1414 g(AD)	4753.1	0.25	—	—	—	—	—	0.69	0.17
Ghanaian			976 g(OD)									

NOTE: All weights and volumes are rounded to the nearest whole number after calorific values have been calculated.

mance. The addition of an oven, as in the Ghanaian cooker, would be welcomed by Fijian women. Most of those interviewed do bake and would like to do so more often (buns, scones, and bread for breakfast are popular).

Smokeless wood stoves, such as the two tested, are already acceptable. Interest was expressed in these stoves during our survey. They are inexpensive as the cost of material for their construction would only be about $30, approximately 6% of the villlages' household mean annual cash income (Brace Research Institute 1976). Their running costs, assuming that there is no real resource cost (opportunity cost) of labour in villages, are effectively nil. Firewood is plentiful and still free in most rural areas. However, the problem of durability still needs to be explored further. Modification in design that would allow for the replacement of worn out part would be an advantage.

At present only five molds of the Indian chula stove are available for the whole of Fiji. Any housewife wishing to build one must of necessity wait a long while. Therefore, more molds should be built or parts of the stove constructed in sufficient quantities and be easily assembled.

The addition of an ash tray under a grating at the bottom of the fireplace would make cleaning easier and ensure a consistently clear smoke passage. The use of oven material more durable than an oil drum and more efficient use of wood through modification of fireplace design, are other possible improvements. Despite the fact that our tests have not demonstrated a definite increase in thermal efficiency over the open fire, the smokeless wood stove certainly greatly reduces fire and health hazards. Even for this alone, its introduction on a large scale into rural homes is worthy of consideration.

The latest wood stove designed by the Fiji Forestry Department, and still at the experimental stage, attempts to incorporate the improved features suggested above. The CASD continues to be involved in this development.

Charcoal Burners

Although not tested as yet for fire risk, the charcoal stove that is used is of sturdy design, which suggests much less fire risk than either of the kerosene stoves tested. Of the kerosene stoves one was rated as posing very high fire risks by the New Zealand Consumer Council. This fact together with the results of the tests as shown in Table 39 suggests that charcoal could be developed as an alternative cooking fuel to kerosene.

Table 40. Fuel consumption and baking time compared.[a]

Cooker type	WT (min)	CT (min)	Fuel Amt	Fuel kcal	EI	Oven temp. (°C)	WT (min)	CT (min)	Fuel Amt	Fuel kcal	EI	Oven temp. (°C)	Total	Mean
Kerosene														
Bombay pot over Hong Kong wick	52	29	158 ml (129.40 g) + (702 g)[b]	1141.1 + (4506.8)	0.81	149–315	40	30	185 ml (151.5 g) + (680 g)	1652.3 + (4365.6)	0.87	149–232	1.68	0.84
Bombay pot over Swedish pressure stove no. 1	48	20	107 ml (87.63 g) + (992 g)	955.64 + (5919.2)	0.69	140–204	25	30	165 ml (135.1 g) + (340 g)	1473.7 + (2182.8)	1.45	149–232	2.14	1.07
Charcoal														
Forestry model oven[c]	57	43	618 g(OD)	4356.9	1.12	149–315	45	48	605 g(OD)	4265.3	1.24	149–204	2.36	1.18
Bombay pot over cooker	30	27	556 g(OD)	3919.8	1.24	149–204	22	32	715 g(OD)	5040.8	1.05	149–204	2.29	1.15
Wood														
Bombay pot over open fire	26	17	2241 g(AD) 1636 g(OD)	7967.3	0.61	204–315	12	42	1772 g(AD) 1232 g(OD)	5999.8	0.88	149–232	1.49	0.75
Bombay pot Indian chula oven	34	29	3959 g(AD) 2890 g(OD)	14074.3	0.35	149–315	45	22	3435 g(AD) 2287 g(OD)	11137.7	0.48	149–204	0.83	0.42
Modified Ghanaian	22	15	1372 g(AD) 1002 g(OD)	4879.7	1	149–315	18	16	1566 g(AD) 1088 g(OD)	5298.6	1	149–260	2	1

[a] WT = warming up time, CT = cooking time, EI = efficiency index = calories expended by modified Ghanaian oven/calories expended by cooker, OD = oven dry, and AD = air dry.

[b] Amount of charcoal placed on Bombay pot.

[c] Charcoal consumption can be much lower because the iron plate at the bottom of the oven was not removed for these tests. When removed, the oven temperature reaches 315°C in 10 min.

Because 1 g of air-dried high density wood yields on average; 0.15 g of charcoal (Richolson and Alston 1977) then replacement of wood by charcoal should not be contemplated where firewood supplies are close and plentiful. Our results indicate that calorific loss during the conversion (wood/charcoal) is not sufficiently compensated for by increased efficiency of the charcoal cooker.

Charcoal burners have a potential in those periurban and rural areas where firewood supplies are poor and kerosene is the normal fuel for cooking. Richolson and Alston (1977), by comparing quantity of fuel burned per minute, calculated that charcoal has to be sold at less than $0.085/kg to compete with kerosene at current prices ($0.79/Imp. gallon).[7] Based on actual fuel burned per meal our test results indicate a competetive upper limit (at the same kerosene prices) of $0.06/kg for charcoal.[8] This is too low a price to attract potential charcoal producers. Nevertheless, as the price for kerosene increases, charcoal production should become more attractive.

[7] The 1977 retail price of kerosene in urban Suva was $0.79/imperial gallon, but prices in periurban and rural areas are usually higher.

[8] The efficiency index (EI) from Table 39 for the charcoal cooker is 0.32 (the EI expressed in kcal × 10.905 is 34.06 kcal), the primus no. 1 is 1 (10.905 kcal), and the Hong Kong wick is 0.59 (18.43 kcal). The consumption equivalents are 3.13 kcal, 1 kcal, and 1.69 kcal respectively. Weight of fuel for the charcoal cooker is 4.8 kg, primus no. 1, 1 kg, and the Hong Kong wick is 1.69 kg. Therefore, (a) with kerosene burners as efficient as the primus no. 1, 4.8 kg of charcoal has to cost the same as 1 kg kerosene ($0.212/kg) or $0.212/4.8 = $0.04 for every kg of charcoal; (b) with kerosene burners like the Hong Kong type 2.8 kg charcoal gives equivalent cooking capacity to 1 kg kerosene, which means a price of $0.08/kg for charcoal. This figure has been accepted here as Hong Kong cookers are cheaper and more commonly used; and (c) mean oven-dry weight = 76.03% air-dry weight, therefore, 1 kg oven-dry weight = 1.3 kg air-dry weight, therefore, competitive price for 1 kg air-dry weight = $0.08/1.32 = $0.06.

Table 41. Estimated thermal efficiency of common cookers in rural homes.

Cooker	Fuel used	% efficiency[a]	NZCC results[b]
Open fire	Wood	5–10	
Indian chula	Wood	4–6	
Lovo (ground oven)[c]	Wood	3–5	
Hong Kong 10 wick	Kerosene	15–29	37.7%
Swedish primus no. 1	Kerosene	30–57	27.5%

[a] Because of variations in atmospheric pressure and cooking styles, the efficiency was obtained by averaging two efficiencies: one obtained by boiling 1 litre of water from ambient temperature to 60°C, and the other by carrying out the same boiling up to 100°C from ambient temperature. In both cases the fuel consumed was carefully measured and converted to energy consumed by using the measured calorific values (see also Tables 39 and 40).

[b] Results of tests carried out in 1976 by the New Zealand Consumer Council (NZCC) by boiling 2 litres of water. Contrary to the NZCC results general experience of users in Fiji would place the Swedish primus as being more efficient than the Hong Kong 10 wick burner.

[c] Water was not boiled in the earth oven (lovo). Instead the lovo efficiency was calculated by comparing fuel used per kg of food by the lovo and fuel used per kg of food by the open fire.

Taking a 15% yield of charcoal from air-dried wood (Richolson and Alston 1977) the cost in the field of coconut wood equivalent to 1 kg of charcoal is 2.67¢. This estimate is derived as follows: cost of 1 tonne air-dry coconut wood at site = $4.00 (see Table 22), therefore, the cost of 1 kg of coconut wood at site = 0.40¢. But 1 kg air-dry wood yields 0.15 kg charcoal, therefore, 1/0.15 = 6.67 kg air-dry coconut wood yields 1 kg charcoal (6.67 × 0.4¢) or 2.67¢ of air-dry coconut wood yields 1 kg charcoal.

If coconut charcoal is to sell in Suva at 6¢/kg so that it may be competitive with kerosene, its production, transportation, and handling should not exceed 3.3¢/kg. According to estimates quoted on Table 22 cost of handling and transportation to Suva of air-dry coconut wood is approximately 1.8¢/kg. Because of its greatly reduced bulk and therefore ease of handling, charcoal transportation and handling costs should be less.

It should be noted that at 6¢/kg coconut wood charcoal and 2¢/kg air-dry coconut wood cooking a meal with charcoal will be slightly more expensive than cooking the same meal over an open fire with coconut wood. This conclusion has been derived from the results of our tests as shown in Table 39. The mean efficiency index of the Swedish primus is 1, the charcoal burner is 0.32, and the open fire is 0.18. Therefore, for every x kilocalories expended by the Swedish primus to cook a given meal: (1) the charcoal cooker expends (x/0.32) kcal and (2) the open fire expends (x/0.18) kcal. But calorific value of coconut charcoal is 7.05 kcal/g and calorific value of coconut wood is taken as 4.7 kcal/g (Wiersum 1977). Therefore, (x/0.32) (1/7.05) g charcoal = (x/0.18) (1/4.7) g coconut wood or (0.44 x) g charcoal = (1.18 x) g coconut wood, that is 1 kg charcoal = 2.68 kg coconut wood, therefore, 6¢ charcoal = 5.36¢ coconut wood.

Charcoal cooking is smokeless and occupies less space than wood. Unless wood stoves that are more efficient than an open fire are used, charcoal cooking with the Fiji Forestry Department's model, appears to be a potential alternative to kerosene cooking in the homes of middle- and lower-income groups in semirural and urban settlements. It is assumed that charcoal will be produced in the coconut plantations and not in Suva. For the producer and seller of wood, it is still more lucrative to sell wood rather than charcoal to compete with kerosene, because 6.67 kg of wood will bring at least 13¢ at Suva (Table 22), but 1 kg of charcoal obtained from the same quantity of wood will bring only 6¢.

Our survey of rural households indicates an increase in kerosene consumption for cooking as annual gross cash income increases from \$100 to \$2000 per household. In the majority of these households kerosene is one of two or more cooking fuels. For households with an income below \$2000 the other fuel is usually wood — above that, it may be wood, gas, or electricity. Proportionate use of electricity or gas is expected to increase as cash income increases. Fig. 18 shows the relationship between annual cash income (for 1977) and kerosene consumption for cooking. The two are positively and highly correlated. Fig. 19 shows the relationship between an increase in daily wage rate of Fiji's wage earning population and the national kerosene consumption. Again a close relationship is indicated.

Table 42 summarizes kerosene consumption for lighting in our sample population. The F test for the relation between lighting fuel consumption and annual cash income is not significant even at the 5% level, which

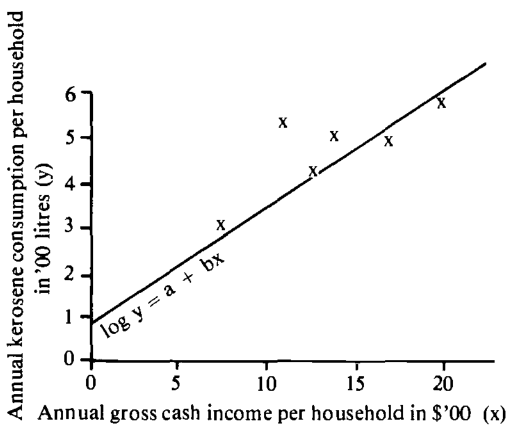


Fig. 18. *Kerosene consumption for cooking and annual gross cash income of households surveyed, (a = 0.66, b = 0.3, r = 0.9, $F_{(1,4)}$ = 17.66, and the confidence limit = 97.5).*

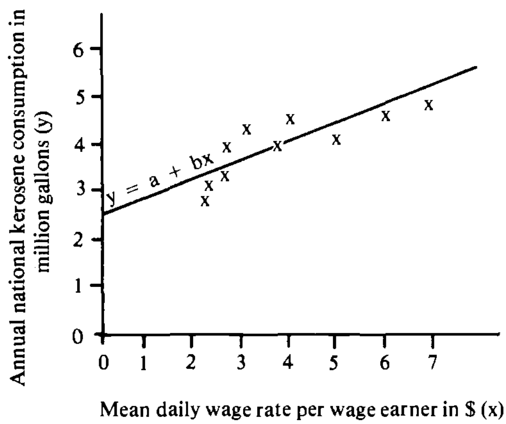


Fig. 19. *National daily wage rates and national kerosene consumption, (a = 2.53, b = 0.4, r = 0.85, t = 4.37, and the confidence limit = 99.5).*

Table 42. Kerosene consumption for lighting and annual cash income per household (sample of 15 households).[a]

X	Y	Y = a + bx	log y = a + bx
1.5	0.471	b = 0.0386	b = 0.05
4.5	0.575	a = 0.3529	a = 0.54
7.5	0.541	r = 0.7885	r = 0.8247
10.5	0.574	F(1,3) = 4.9338	F(1,3) = 6.389
13.5	1.051	Not significant	Not significant

[a] X = midpoint of income bracket in $'00. Y = mean annual kerosene consumption in '00 litres.

Table 43. Income elasticity of demand test kerosene consumption for cooking and annual cash income per household (sample of 129 households).[a]

X	Y	$Y = a + x^b$	log y = a + bx
1.5	0.0128	a = 1.004	b = 0.299
7.5	0.1795	b = 1.5222	a = 0.663
10.5	2.340	r = 0.9965	r = 0.903
13.5	1.5721	F(1,4) = 566.9208	F(1,4) = 17.659
16.5	1.6090	Confidence level = 99.9%	Confidence limit = 97.5%
19.5	3.510		

[a] X = midpoint of income bracket in $'00. Y = mean annual kerosene consumption in '00 litres.

confirms our belief that kerosene consumption for light will not vary much between different income groups because lighting demands are fairly standard. The mean kerosene consumption for lighting per household is 61.0988 litres annually. This gives an estimated 3 621 265 litres of kerosene for lighting in 1976, leaving 19.038×10^6 litres mostly for cooking and refrigeration.[9] The estimated consumption for cooking is 18 055 432 litres.

[9] The 1976 Census lists the number of rural households as 59 269. The same figure has been assumed for 1977. Census definition of rural excludes what we have termed semirural or periurban. The periurban/semirural areas are largely supplied with electricity that is used for lighting, however, the census count of rural households is the best estimate available for partially or completely kerosene-lit homes.

Table 43 is an analysis of the elasticity of demand between kerosene consumption for cooking and a household's annual cash income. This reveals a close relationship between the use of kerosene for cooking and increase in annual cash income for rural and semirural homes. Data on daily wage rates and national kerosene consumption are listed in Table 44. From the elasticity test, consumption of kerosene for cooking can be predicted with a high degree of confidence (99.9%) to increase 1.5% for every 1% increase in cash income in the middle- and lower-level income brackets. At present, kerosene cookers are much easier to use than open-wood fires. Smokeless wood stoves and charcoal cookers may be able to compete. For periurban and rural areas with no wood, charcoal may be the alternative. A 25% substitution by charcoal would mean an annual production of at least 13 678 358 kg charcoal (based on estimates from our

Table 44. Daily wage rates and national kerosene consumption. (Data from National Published Statistics.)

Year	X Mean daily wage rate ($)	Y Total national kerosene consumption (million gallons)[a]	Y = a + bx
1968	2.2	2.83	a = 2.535 r = 0.8555
1969	2.32	3.08	b = 0.385 t = 4.37
1970	2.47	3.42	Confidence limit > 99.5%
1971	2.72	3.90	
1972	3.08	4.35	
1973	3.98	4.53	
1974	4.9	4.18	
1975	5.97	4.77	
1976	6.68	4.98	

[a] One imperial gallon equals 4.55 litres.

tests that 0.33 litres kerosene = 1 kg air-dry charcoal).[10]

Conclusions

Our tests point to the need:

1) to find better designed kerosene cookers for increased efficiency and greater safety;[11]

2) to develop wood burners that are more efficient and healthier to use than an open fire — even when raised. Improvements in the design of the chula and the Ghanaian stoves may be sufficient; and

3) to take a serious look at both charcoal and wood as alternative cooking fuels to kerosene for many homes. The Fiji Forestry Department's efforts should be supported with more research inputs.

[10] Kerosene specific gravity is 0.819, therefore, 1 kg kerosene = 1.22 litres kerosene, but as noted in footnote 8, 2.8 kg oven-dry charcoal = 1 kg kerosene on a Hong Kong cooker, therefore, 1.3 × 2.8 kg air-dry charcoal = 1 kg kerosene = 1.22 litres, therefore, 1 kg charcoal = (1/1.3)(1.22/2.8) litres = 0.33 litres kerosene.

[11] Kerosene cookers on the market at present are largely inefficient and vary greatly in efficiency (New Zealand Consumer Council test reports). The particular cooker we used, the Hong Kong cooker, was found to be only 15.7% efficient (see Table 41).

Recommendations

- That in view of the findings of the New Zealand Consumer Council's tests on common kerosene cookers in Fiji, the government should initiate steps to prevent the sale of dangerous devices that fail to meet safety standards. The formation of a body to set and enforce standards for cookers and allied apparatus may help.

- That because charcoal yield from wood is only 15–20%, and as presently available charcoal burners are not efficient enough to compensate for the loss in energy during the conversion of wood to charcoal, the government should encourage the use of both wood and charcoal for semirural and urban homes as alternatives to kerosene.

- That government encourage the development and use of efficient wood-burning stoves wherever possible.

Electrification by Small Autogenerators for Rural Communities

Introduction

The Fiji Public Works Department (PWD) in response to a directive from Cabinet installed the first government-supported diesel generators in 1975 at two villages. The total number of generators installed is expected to reach 24 by the end of 1978 and will increase by approximately one dozen every year thereafter. The upper limit of this growth will be determined by the PWD's ability to service the scattered plants regularly. This may limit the communities that are served to 300 villages.

In the first 2 years of the scheme, the village contributed one-third of the total costs and the government contributed two-thirds. Since 1977, the village contribution has been reduced to one-sixth, to a maximum of \$50 per bure. Maintenance is done by the PWD with \$100 annual contribution from the village. The scheme fulfills the social aims of improving lighting conditions in rural low-income homes at a charge to the consumers that is below cost.

It is envisaged that of Fiji's 3055 rural villages and settlements about 1000 may ultimately be served by extensions of the various Fiji Electricity Authority's (FEA) urban grids and other potential electricity schemes. Of the remaining 2000, up to 300 villages and settlements will probably be served by the PWD scheme, which leaves about 1700 villages and settlements still uncatered to.

Which of the settlements and villages is to be served by the government subsidized scheme is in part determined by the Ministry of Rural Development and by each community's ability to pay and to join the waiting list early enough. Because of the high reticulation costs, it is obvious (and already illustrated by the case of a cane farm settlement) that only the closely-settled centres, such as Fijian villages, will benefit from the scheme. For settlements of isolated leasehold farmers, the costs will be above the stipulated maximum of \$50 per dwelling.

Villages connected to an FEA grid initially contribute 40% of the capital costs of connection. The average bearable contribution from any applicant to the FEA is \$300–\$350. A consumer connected to an FEA grid is expected to purchase annually electricity that costs the equivalent of at least 20% of the initial connection costs within the first 5 years. The consumer's 40% contribution is refundable after 5 years if the consumption level exceeds the stipulated minimum (i.e., 20% of initial costs annually). A small community of 15 dwellings recently had to pay \$38/dwelling as a deposit and guarantee a minimum \$19/year/household consumption for the first 5 years.

Under the PWD rural electrification scheme, domestic power needs of villages are estimated in terms of lighting needs. Although the scheme also intends to serve other small domestic needs, the cost of apparatus required for end use (e.g., refrigerators, stoves, water heaters, and radios) is too costly for most villagers.

In August 1978, the PWD had installed, or had surveyed and was waiting to install, 74 small, diesel-generated electricity systems. The size of the generators, the number of households in the villages they serve, the number and type of lighting they provide, and the costs involved are summarized in Table 45. The table shows PWD's generator size allocations resulting in 32 villages of 17–30 dwellings allocated 10 kW generators; 23 villages of 40–50 dwellings, 15 kW generators; 10 villages of 60–80 dwellings, 20 kW generators; 3 villages of 70–90 dwellings, 30 kW generators; and 2 villages with over 100 dwellings allocated 40 kW generators.

As already noted in Table 6 the majority (49%) of lamps used in rural areas are kerosene lamps of low-light intensities (up to 3.5 footcandles at 30 cm distance). People's responses to our interviews confirmed the need and desire for better lighting in rural areas. As a solution, the Fiji government is offering diesel-generated electric lighting by small autogenerators.

This Study

Of the four case study villages, Nacamaki, was one of the initial two villages to obtain a diesel generator under the scheme. Because of its electric lighting system, this village has a much lower commercial fuel consumption than any other case study as shown in Table 17. Another of

Table 45. Frequencies, costs, and end uses of installed and planned small diesel electricity systems in Fiji's rural areas.

Total number of villages	Generator size (kW)	Number of settlements	Mean number of dwellings	Total scheme cost ($)	Village contribution ($)	Incandescent bulbs	Fluorescent tubes
2	6	2	15	4876	1125	n.a.[a]	n.a.
1	9.5	1	40	4900	3300	34	4
32	10	1	17	3315	900	34	4
	10	1	School	4723	n.a.	20	22
	10	9	25	8685	1382	55	5
	10	1	30	8800	1500	60	4
	10	20	25	8340	1799	46	9
1	10	1	45	13213	4863	n.a.	n.a.
23	15	4	49	14329	2297	104	12
	15	19	44	14185	2366	104	16
10	20	5	76	15724	3079	181	7
	20	5	63	16977	2830	125	10
3	30	2	79	28223	3679	164	n.a.
	30	1	89	22981	3900	180	30
2	40	1	160	38320	6400	320	10
	40	1	n.a.	19000[b]	n.a.	n.a.	n.a.

[a] n.a. = information not available.
[b] 1975 price.

our four case study villages, Natia, which was the site of the wind-generated electricity system, had a 6 kW diesel generator installed in the first quarter of 1978. Of our four case studies, only these two villages had a mean 1977 annual cash income per household of over $800.

This section offers an economic assessment of the diesel electricity generation system. It is accepted that the scheme is not intended to be economic, but it is hoped that knowledge of the actual extent of subsidy may aid decision-makers in formulating future policies.

Investigation Method

The bulk of our information was obtained from the files of the Public Works Department, Rural Electrification Section. Information on fuel consumption and actual running costs was obtained from some existing operators such as Nacamaki village cooperative, Fulton Missionary College, the Fiji Forestry Department, and from the Fiji Education Department.

The Sample

Five systems of 10 kW, 15 kW, 20 kW, 30 kW, and 40 kW were selected for analysis. Representative villages from each category (as shown in Table 45) were selected on the basis of the number of dwellings and total scheme cost. These were as follows:

(1) *10 kW*: A village with 25 dwellings and a total scheme cost of $8340 was selected. This village is located off the coast of Vanua Levu.

(2) *15 kW*: A village with 44 dwellings and a total scheme cost of $14 185 was selected. This is an interior village on Viti Levu.

(3) *20 kW*: Of this category a village with a total scheme cost of $16 977 was selected. It is located in the Lau Group.

(4) *30 kW*: The selected village for this category is also in the Lau Group. Its total scheme cost is $22 981.

(5) *40 kW*: Only one of the two villages with 40 kW generators had adequate information available. This village, located on an island off the Southwest coast of Viti Levu, was selected.

Benefit/Cost Analysis

(1) *Capital Costs:* The capital costs of the generator systems were obtained from the Public Works Department. An additional \$500[12] is added to each system's initial capital outlay to cover the costs of supervision by the professional engineer and the office work involved with the survey and installation.

(2) *Running Costs:* The running costs include the cost of parts that need to be replaced regularly and other materials that are necessary for maintenance, the cost of transport for PWD mechanics for servicing, labour costs for operation, labour costs for maintenance, and fuel costs. Fuel costs include the cost of diesel oil and of oil at Suva and the cost of handling and of transportation to the village. The latter component is estimated following the Nacamaki village cooperative's formula. They add 40¢ to the price of every 4.55 litres of fuel for transportation and handling. For our analysis, we have added for every 4.55 litres of fuel: 20¢ for a Viti Levu destination outside Suva, 40¢ for a first port outside Suva and Viti Levu, and 60¢ for a second port (two handling centres) outside Viti Levu. The capital costs and running costs of the sample generators are set out in Tables 46–51.

(3) *Benefits:* Because electric lights provide lighting of approximately equal intensities to the common benzine gas lamps, minimum benefits have been valued in terms of the equivalent benzine fuel saved:

(a) Every light bulb and fluorescent tube is considered as equivalent to one benzine lamp.

(b) A benzine gas lamp consumption is taken to be 1.74¢/h (see Table 6) from the survey data.

Benzine costs have not been varied with geographical locations as was done for diesel costs. This is because all villages already have an established benzine distribution system, through which they purchase benzine not communally but individually. They may through choice purchase benzine either from the local shop, or in greater quantity from the nearest urban centre, or at Suva. The price range available to them will probably be similar to those available to our case study populations. On the other hand, diesel oil for the community generator has to be purchased communally by a village body delegated with the responsibility. Thus, prices are likely to be standardized along the principles followed by the Nacamaki cooperative.

(c) It is estimated therefore that 1 h of electric lighting is a benefit of 1.74¢.

(4) Net Present Value and Benefit/Cost Ratio: The Net Present Value (NPV) and Benefit/Cost Ratio (B/C) are calculated at three discount rates (7.5%, 10%, and 12.5%) and with three foreign exchange shadow price factors (1.0, 1.2, and 1.4). These are presented in Tables 52 and 53. For ease of computing and to give algebraic insight the net present values here were obtained by continuous discounting. These are not significantly different from the values obtained by discrete discounting methods.[13] For example, at a 7.5% discount rate the NPV is only 4% less with discrete discounting. At 10% it is 3% less, and at 12.5% it is 2% less.

The net present value and benefit/cost ratio are derived following Medford (1973) as follows:

[12] The additional \$500 was determined as follows: 1 week, mechanical engineer (professional) at \$9900/year = \$190; 1 × 2 weeks, mechanical engineers (technicians) at \$2321/year each = \$89; 1.5 weeks mechanical engineer (supervisor) at \$5753/year = \$165; 0.5 weeks, draftsman at \$3201/year = \$30; and 0.5 weeks, office clerk at \$2321/year = \$22 for a total of \$496.

[13] It can be shown that $r/100 = \log_e 1 + r^1$ where r = discrete discount rate and r^1 = continuous discount rate. Therefore, if $r = 0.05$, then $r/100 = \log_e 1.05$. Therefore, $r = 0.0488$ or 4.9%.

Table 46. Costs at different foreign exchange shadow price factors for Generator A (10 kW), Cikobia Island. (A total of 32 × 10 kW systems so far.)

	Capital costs ($)	Foreign (%)	Local (%)	Shadow price factors ($) 1.0	1.2	1.4
Generator	2994	84	(16)	2515 (479)	3018 (479)	3521 (479)
Reticulation materials and extras	3147	51	(49)	1605 (1542)	2408 (1542)	2247 (1542)
Power house materials	1200	50	(50)	600 (600)	720 (600)	840 (600)
Cable tiles	375	51	(49)	195 (180)	234 (180)	273 (180)
Transport — initial installation materials	350	20	(80)	70 (280)	84 (280)	98 (280)
Transport — skilled and semiskilled labour	150	43	(57)	65 (85)	77 (85)	91 (85)
Labour — semiskilled for installation	800 (× 1)			800	800	800
Labour — supervision and survey	500 (× 1)			500	500	500
Labour — installation (unskilled — village labour — no costs)	—					
Total capital				9516	11007	11536
Running costs						
Fuel	1680	61	(39)	1025 (655)	1230 (655)	1435 (655)
Materials	100	56	(44)	56 (44)	67 (44)	78 (44)
Transport	200	43	(57)	86 (114)	103 (114)	120 (114)
Labour — operator	91 (× 0.5)			46	46	46
Labour — maintenance	216 (× 1)			216	216	216
Total annual running costs				2242	2475	2708

(a) Present Value (PV) or Discounted Benefit ($\bar{B}$):

$$PV = \frac{b}{r-\alpha}\left(1-e^{-(r-\alpha)T}\right)$$

where b = annual benefit, α = rate of fuel price increase, r = discount rate, and T = time.

(b) Discounted Costs ($\bar{C}$):

Total discounted costs include initial capital, running, and maintenance costs as follow:

$$\bar{C} = xC + \frac{l}{r-\alpha^1}\left(1-e^{-(r-\alpha)T}\right)$$

where xC = intial capital outlay, l = labour costs, α^1 = rate of increase in labour costs, and f = fuel and spare parts.

It is assumed that a rise in costs of spare parts will be tied to increases in fuel prices because the manufacturing and transport costs of spare parts will be largely dependent on fuel costs.

(c) Net Present Value (NPV):

Table 47. Costs at different foreign exchange shadow price factors for Generator B (15 kW), Serea. (A total of 23 × 15 kW systems so far.)

	Capital costs ($)	Foreign (%)	Local (%)	Shadow price factors ($) 1.0	1.2	1.4
Generator	4114	84	(16)	3456 (658)	4147 (658)	4838 (658)
Reticulation materials and extras	1736	51	(49)	885 (851)	1062 (851)	1239 (851)
Power house materials	1200	50	(50)	600 (600)	720 (600)	840 (600)
Cable tiles	4000	51	(49)	2040 (1960)	2448 (1960)	2856 (1960)
Transport — initial installation materials	40	25	(75)	10 (30)	12 (30)	14 (30)
Transport — semiskilled labour	10	25	(75)	3 (7)	4 (7)	5 (7)
Labour — semiskilled for installation	900 (×1)			900	900	900
Labour — supervision and survey	500 (× 1)			500	500	500
Labour — installation (unskilled — village labour — no costs)	—					
Total capital				12500	13899	15298
Running costs						
Fuel	1408	64	(36)	901 (507)	1081 (507)	1261 (507)
Materials	150	56	(44)	84 (66)	101 (66)	118 (66)
Transport	20	43	(57)	9 (11)	10 (11)	13 (11)
Labour — operator	91 (× 0.5)			46	46	46
Labour — maintenance	216 (× 1)			216	216	216
Total annual running costs				1840	2038	2238

NPV = $\bar{B}-\bar{C}$ = PC$-\bar{C}$. The prices have been fixed to 1977 values. Therefore,

$$NPV = \left((1-e^{-rT})\frac{b-f-l}{r}\right)-xC$$

Discussion

As evident in Table 52 the majority of diesel generated electric lighting systems for villages are not economically viable. Villages in Fiji range in size from 20–1000 dwellings with the average village consisting of 200 people in 22 dwellings (1974 and 1976 Public Works Department surveys). Therefore, it is expected that the 10 kW, 15 kW, and 20 KW generators will be more numerous than larger generators.

Table 53 shows that in terms of actual returns to the villagers on their contributions, those systems with 15 kW or more are satisfactory. Table 54 shows that the cost of producing 1 h of electric lighting by this scheme varies from 1¢/lamp/h to 3¢/lamp/h. Benzine gas lamps (also taking lamp depreciation into account) provide lighting at a cost of 1.86¢/h. Again only the large systems (30 kW and 40 kW) produce light at less cost than the benzine gas lamp.

In terms of electricity unit costs, the most viable village system (40 kW) generates electricity at a cost of 10¢/kWh as compared to the Fiji Electricity Authority's overall average cost of 8.9¢/kWh generated. However, there are other benefits that should be considered. To the consumer electric lighting means good lighting at the flick of a switch, but benzine gas lamps mean an increased fire risk, because the fuel is so flammable, as well as having to make frequent trips to the shop to purchase fuel. But a community lighting system makes the villager dependent on someone else for reliable lighting. When management fails, power cuts mean erratic supplies and, therefore, undependable lighting. In addition, the benzine gas lamp is portable and is frequently used for fishing and for outdoor activities. (The Public Works Department electrification scheme does not provide street or toilet lighting.)

Table 48. Costs at different foreign exchange shadow price factors for Generator C (20 kW), Vanua Balavu. (A total of 10 × 20 kW systems so far.)

	Capital costs ($)	Foreign (%)	Local (%)	Shadow price factors ($) 1.0	1.2	1.4
Generator	4836	84	(16)	4062 (774)	4875 (774)	5687 (774)
Reticulation materials and extras	8288	51	(49)	4227 (4061)	5072 (4061)	5918 (4061)
Power house materials	1200	50	(50)	600 (600)	720 (600)	840 (600)
Cable tiles	1100	51	(49)	561 (539)	673 (539)	785 (539)
Transport — initial installation materials	800	20	(80)	160 (640)	192 (640)	224 (640)
Transport — semiskilled labour	200	43	(57)	86 (114)	103 (114)	120 (114)
Labour — semiskilled for installation	1000 (× 1)			1000	1000	1000
Labour — supervision and survey	500 (× 1)			500	500	500
Labour — installation (unskilled — village labour — no costs)	—					
Total capital				17924	19863	21802
Running costs						
Fuel	1754	51	(43)	1000 (754)	1200 (754)	1400 (754)
Materials	200	56	(44)	112 (88)	134 (88)	157 (88)
Transport	150	55	(45)	83 (67)	100 (67)	116 (67)
Labour — operator	91 (× 0.5)			46	46	46
Labour — maintenance	216 (× 1)			216	216	216
Total annual running costs				2366	2605	2844

Table 49. Costs at different foreign exchange shadow price factors for Generator D (30 kW), Cicia. (A total of 3 × 30 kW systems so far.)

	Capital costs ($)	Foreign (%)	Local (%)	Shadow price factors ($) 1.0	1.2	1.4
Generator	6769	84	(16)	5686 (1083)	6823 (1083)	7960 (1083)
Reticulation materials and extras	11812	51	(49)	6024 (5788)	7229 (5788)	8434 (5788)
Power house materials	1200	50	(50)	600 (600)	720 (600)	840 (600)
Cable tiles	1000	51	(49)	510 (490)	612 (490)	714 (490)
Transport — initial installation materials	600	20	(80)	120 (480)	144 (480)	168 (480)
Transport — skilled and semiskilled labour	100	20	(80)	20 (80)	24 (80)	28 (80)
Labour — semiskilled for installation	1500 (× 1)			1500	1500	1500
Labour — supervision and survey	500 (× 1)			500	500	500
Labour — installation (unskilled — village labour — no costs)	—					
Total capital				23481	26073	28665
Running costs						
Fuel	2374	59	(41)	1401 (973)	1681 (973)	1961 (973)
Materials	300	56	(44)	168 (132)	202 (132)	235 (132)
Transport	200	43	(57)	86 (114)	103 (114)	120 (114)
Labour — operator	91 (× 0.5)			46	46	46
Labour — maintenance	216 (× 1)			216	216	216
Total annual running costs				3136	3467	3797

The economic analysis results show that:

(a) The majority of diesel systems for villages are not going to be economically viable (93.8% of those surveyed so far).

(b) The cost of production of electric lighting, in the majority of systems, is higher than that for the equally bright benzine lighting.

(c) The electric system is dependent on good management, community cooperation, and efficient PWD servicing for its continuance, and as long as the electric system is utilized for lighting alone it is evident that subsidized benzine gas or kerosene tilley lamps will be of greater economic benefit to the majority of villages.

According to a World Bank paper (IBRD 1975), initial low economic returns from rural electrification projects should not deter their promotion, because demands usually increase and electricity use diversifies with time, which results in much greater economic activity in rural areas. This is true where household consumption is coupled

Table 50. Costs at different foreign exchange shadow price factors for Generator E (40 kW), Vatulele. (A total of 2 × 40 kW systems so far.)

	Capital costs ($)	Foreign (%)	Local (%)	Shadow price factors ($)		
				1.0	1.2	1.4
Generator	9000	84	(16)	7560 (1440)	9072 (1440)	10584 (1440)
Reticulation materials and extras	19520	51	(49)	9955 (9565)	11946 (9565)	13937 (9565)
Power house materials	1200	50	(50)	600 (600)	720 (600)	840 (600)
Cable tiles	36000	51	(49)	1836 (1764)	2203 (1764)	2570 (1764)
Transport — initial installation materials	900	20	(80)	180 (720)	216 (720)	252 (720)
Transport — skilled and semiskilled labour	100	20	(80)	20 (80)	24 (80)	28 (80)
Labour — semiskilled for installation	4000 (× 1)			4000	4000	4000
Labour — supervision and survey	500 (× 1)			500	500	500
Labour — installation (unskilled — village labour — no costs)	—					
Total capital				38820	42850	46880
Running costs						
Fuel	2994	61	(39)	1826 (1168)	2192 (1168)	2556 (1168)
Materials	400	56	(44)	224 (176)	269 (176)	314 (176)
Transport	150	20	(80)	30 (120)	36 (120)	42 (120)
Labour — operator	91 (× 0.5)			46	46	46
Labour — maintenance	216 (× 1)			216	216	216
Total annual running costs				3806	4223	4638

with "productive" consumption of electricity such as in agroindustries and small business. The PWD scheme is not designed to allow for such expansion in general. (In one of our case study villages, Natia, the diesel generator is to provide electricity for an ice-maker and a deep freezer to service the village's fishing industry.)

The use of electricity for productive purposes would require a greater supply of technical skills than is presently available in villages and a greater input of capital and know-how for agro-based industries to be established within or close to villages. Without this development the PWD rural electrification program will continue to meet only the social aims of improving the standard of living in rural villages by providing electric lighting.

Whether rural electrification will contribute to stemming urban drift is doubtful. The World Bank paper previously referred to reports "little concrete evidence concerning the effect of electricity on migration." It quotes investigations that reveal the reasons for migration as being to search for jobs, education, and raising families.

Thus rural electrification to service industries, which will provide jobs, and to provide energy for household consumption, such as for lighting, may be more socially and economically viable than the present electric lighting scheme.

In light of the above conclusion and of the desire for better lighting, particularly for rural school children, and noting that the PWD scheme can only cover a limited number of settlements, the aims of the scheme may be better fulfilled by allocating priority of installations to rural schools and community centres. Such systems could then be extended to nearby villages where economically viable. Furthermore, to enable a greater number of rural homes to receive as good, if not better, lighting than from an electric system, our benefit/cost analysis indicates that subsidizing benzine gas lamps, or even better (because of less flammable and cheaper fuel) subsidizing kerosene tilley lamps, would be effective. A government subsidy of five-sixths on tilley lamps will reduce the Suva retail prices (1978) to \$3.8–\$5 each. These subsidized prices are comparable to those of the cheaper hurricane and standing lamps (see Table 16).

Table 51. Generator benefits at different foreign exchange shadow price factors.

	Capital costs (\$)	Foreign (%)	Local (%)	Shadow price factors (\$) 1.0	1.2	1.4
Generator A						
10 kW fuel	1540	71	(29)	1093 (447)	1312 (447)	1530 (447)
Savings on benzine lamps	73	56	(44)	41 (32)	49 (32)	57 (32)
Total annual benefits				1613	1840	2066
Generator B						
15 kW fuel	2777	71	(29)	1972 (805)	2366 (805)	2761 (805)
Savings on benzine lamps	96	56	(44)	54 (42)	65 (42)	76 (42)
Total annual benefits				2873	3278	3684
Generator C						
20 kW fuel	3894	71	(29)	2765 (1129)	3318 (1129)	3871 (1129)
Savings on benzine lamps	161	56	(44)	90 (71)	108 (71)	126 (71)
Total annual benefits				4055	4626	5153
Generator D						
30 kW fuel	6340	71	(29)	4501 (1839)	5402 (1839)	6301 (1839)
Savings on benzine lamps	290	56	(44)	162 (128)	195 (128)	227 (128)
Total annual benefits				6630	7564	8495
Generator E						
40 kW fuel	9962	71	(29)	7073 (2889)	8488 (2889)	9902 (2889)
Savings on benzine lamps	409	56	(44)	229 (180)	275 (180)	321 (180)
Total annual benefits				10371	11832	13292

Table 52. Benefit/cost analysis of selected village diesel electricity generators.[a]

	Discount rates (%)	Foreign exchange shadow price factors[b] 1.0 NPV ($)	1.0 B/C	1.2 NPV ($)	1.2 B/C	1.4 NPV ($)	1.4 B/C
Generator A	7.5						
10 kW (32	10	b-f-l = −629		b-f-l = −635		b-f-l = −642	
villages)	12.5						
Generator B	7.5	−3198	−0.26	−2733	−0.20	−2277	−0.15
15 kW (23	10	−4475	−0.36	−4266	−0.31	−4064	−0.27
villages)	12.5	−5503	−0.44	−5500	−0.40	−5504	−0.36
Generator C	7.5	−2715	−0.15	−2106	−0.11	−1893	−0.09
20 kW (20	10	−4803	−0.27	−4543	−0.23	−4625	−0.21
villages)	12.5	−6484	−0.36	−6506	−0.33	−6827	−0.31
Generator D	7.5	7981	0.34	10819	0.41	13639	0.48
30 kW (3	10	3663	0.16	5755	0.22	7832	0.27
villages)	12.5	184	0.01	1677	0.06	3155	0.11
Generator E	7.5	20295	0.52	25666	0.60	31136	0.66
40 kW (2	10	12181	0.31	16262	0.38	20428	0.44
villages)	12.5	5646	0.15	8687	0.20	11803	0.25

[a] Net present value (NPV), NPV = $\bar{B} - \bar{C}$, and discounted benefits = $\bar{B}$, discounted costs = $\bar{C}$, B/C = $(\bar{B} - \bar{C})/\bar{C}$.

[b] In all cases annual net benefits are negative, i.e., benefits (b) minus fuel and spare parts (f) and labour (l) are negative.

Table 53. Benefit/cost analysis taking account only of the villages' contributions and benefits accruing to them.[a]

	Discount rates (%)	Foreign exchange shadow price factors[b] 1.0 NPV ($)	1.0 B/C	1.2 NPV ($)	1.2 B/C	1.4 NPV ($)	1.4 B/C
Generator A	7.5						
10 kW	10	b-f-l = −213		b-f-l = −191		b-f-l = −170	
	12.5						
Generator B	7.5	9877	4.94	11679	5.25	13490	5.51
15 kW	10	8247	4.12	9771	4.39	11303	4.62
	12.5	6934	3.47	8234	3.70	9540	3.90
Generator C	7.5	16501	5.68	19528	6.07	22202	6.37
20 kW	10	13838	4.76	16406	5.10	18676	5.35
	12.5	11692	4.03	13891	4.32	15836	4.54
Generator D	7.5	33109	8.49	38567	8.90	43888	9.01
30 kW	10	28029	7.19	32679	7.55	37195	7.63
	12.5	23938	6.14	27936	6.45	31804	6.53
Generator E	7.5	58713	9.17	67909	9.61	77341	10.31
40 kW	10	49775	7.78	57618	8.16	65696	8.76
	12.5	42577	6.65	49329	6.98	56316	7.51

[a] Net present value (NPV), NPV = $\bar{B} - \bar{C}$, and discounted benefits = $\bar{B}$, discounted costs = $\bar{C}$, B/C = $(\bar{B} - \bar{C})/\bar{C}$.

[b] In all cases annual net benefits are negative, i.e., benefits (b) minus fuel and spare parts (f) and labour (l) are negative.

Table 54. Cost of producing one hour of lighting by the diesel generator systems (assuming that the generators run for 1735 h/year as based on the Nacamaki experience).[a]

	Generators and number of lamps				
	A (51 lamps) ($)	B (92 lamps) ($)	C (129 lamps) ($)	D (210 lamps) ($)	E (330 lamps) ($)
Running costs per year					
Real costs	2242	1840	2366	3136	3806
Cost to village	1826	1554	1900	2520	3140
Depreciation					
Real rate	514	737	1028	1385	2221
Rate to village	82	118	165	222	355
Total costs					
Real cost	2756	2577	3394	3521	6027
Cost to village	1908	1672	2065	2742	3495
Cost of 1 h of light through each lamp					
Real costs	0.03	0.02	0.02	0.01	0.01
Cost to village	0.02	0.01	0.01	0.01	0.01
Therefore cost of producing 1 kWh of light through each lamp					
Real costs	0.19	0.12	0.08	0.08	0.10
Cost to village	0.13	0.08	0.07	0.06	0.06

[a] Cost = (labour + fuel and parts + depreciation) costs/annual running hours × total number of lamps.

Social Assessment

Introduction

It is generally believed, indeed it is made explicit in Fiji energy plans, that expanded energy input into the rural sector will contribute substantially to overall economic development and lift the standard of living in rural areas. Furthermore, the utilization of indigenous energy sources will indubitably help to decrease dependence on imported petroleum products. To this end the government has introduced generous tax concessions to assist schemes that use local energy resources or conserve imported supplies (see Appendix 2 for the Act introduced in 1975).[14]

[14] Unfortunately, as far as this study could ascertain, almost no advantage had been taken of this Act. During the latter stages of this survey a constructive debate ensued between government officials and investors concerning the reasons for the apparent lack of tax concessions claimed and authorized under the Act. But no clear-cut reasons had emerged at the time of writing this report.

Known investigations sponsored by the Fiji Government in the energy field cover a wide variety of energy sources including solar, wind, hydro, geothermal, and biomass renewable supplies. Proposed developments are mostly for the generation of electricity and the Central Planning Office estimates that these proposals could, together with an expansion of existing systems, bring electrical supplies within the reach of 30% of Fiji's rural villages and settlements. Additionally, another 10% will be handled by the PWD's rural electrification scheme. For the residual 60% of villages and settlements it is conceivable that renewable, unconventional, energy sources could provide viable supplies of limited output if further investigations and experiments are made.

Increased availability of energy supplies could create wider diversification of economic activity in the rural sector. Agro-industries which embrace both primary production and processing, such as canning and packaging, could have expansion potential; and, as a minimum gain, the ability to carry out postharvest preservation would be enhanced. Small scale manufacturing of articles for rural use or sale might also be developed to use labour which presently has a low opportunity cost. Given acceptably low capital costs, enterprises which use renewable resources would not be held hostage economically to escalating oil price. However, it should be emphasized that the use of conventional technology (i.e. diesel generators) for local energy supplies has the possible embedded advantage of training rural peoples, through counterpart training on the spot, in recognized skills which can be sold in the present economy.

Establishment of new enterprises which would diversify the rural economic sector is critically dependent upon the following factors: energy availability; labour availability at an economic price; managerial and technical availability for, at least, the start-up period; raw material supplies; distribution and marketing channels that are not so complicated that they offset inherent economic and possible social advantages; willingness of local societies to accept and sustain entrepreneurial behaviour; and, some degree of preferential treatment from government to offset competitors' advantages of economies of scale in production and market size.

Rural Fiji is such today that the above factors seem more like constraints than input factors. While energy, managerial and technical skills, and optimal distribution and marketing channels can all be provided with concerted government and outside aid, the provision of labour with attitudes and motivation aligned to productive enterprise depends upon the social goals of the rural communities.

Some aid for improving marketing channels and encouraging business skills is now already available through the Ministry of Commerce and Industries and government-supported bodies such as BOMAS (Business Opportunity and Management Advisory Service), FDB (Fiji Development Bank), and NMA (National Marketing Authority).

The molding of attitudes and induction of motivation can rightly be considered intrusive, paternalistic, and a subtle enforcement of alien value judgments. Similarly, it is an imposition of external value judgments for outsiders to continually stress that the most appropriate technology is a low level technology, the latter attitude being reminiscent of offering a modicum of cake to those who might need bread in vaster quantities. Nevertheless, the molding of attitudes and cultivation of motivation in rural populations continues through complex processes. Exposure to religious teaching, advertisements, news media, literature, education, and contact with the outside world all feature prominently in social change.

Some interesting observations on attitudes and behavioural reactions to the development process were made by Bayliss-Smith (1977) in a recent study of Nacamaki, one of the villages covered in our case studies. In his study, which covered the period 1974–1976, he observed that:

(a) Recent changes in land use and time use, and increase in travels outside Koro, resulted in "new material aspirations that can only be satisfied through the cash economy";

(b) Unreliable markets result in the continuing importance of the subsistence sector as an "insurance against short-term price fluctuations and the long-term deterioration in the terms of trade";

(c) Unsatisfied aspirations result in migration;

(d) Koro's growing dependence on trade in the last two decades has not resulted in improvement in material welfare;

(e) From the point of view of the Koro villager, rising productivity in terms of yield per unit area, is rather unimportant and that contribution to the net domestic product of the country is a purely academic concept. "The rather low level of returns and the unreliable behaviour of the prices normally prevailing in the cash sector both serve to dampen interest and involvement, in a way that is perfectly 'economic'", this term encompassing the concept of maximizing utility rather than profit; and

(f) Increasing diversity of income sources, but keeping a high level of self-sufficiency in foodstuffs, is the best means of maintaining and improving the present levels of welfare.

This Study

Had this study continued for longer we should have liked to have delved deeper into the social analysis. Although our project has primarily focused on present energy sources, we have inevitably become interested in the feasibility of developing that potential within the village social and economic setting. Any innovation that aims to involve rural societies cannot succeed unless the people want it and unless they are able to assimilate and build on it. We delved into people's expressed energy wants through interviews. People's expressed wants, however, do not always materialize into actions to achieve them. Therefore, we attempted to identify tangible manifestations or indicators of people's aspirations for change and improvement.

We devised a scoring system or indicators for the following qualities:

(a) enterprise;
(b) self-sufficiency; and
(c) desire for material comforts.

Indicators selected were as follow:

(a) Enterprise: The unit assessed was the household. Indicators were:

(1) whether the household had moved out of the confines of the community unit and settled separately (vakagalala). A household within a village is always secure in the implicit understanding that social ties will provide support in times of need. To break from the village means sacrificing much of that security;

(2) whether the household had any means of private transport (e.g., horse, boat, car, or truck);

(3) whether the adults had individual or shared gardens;

(4) what proportion of agricultural production was sold for cash; and,

(5) whether they owned or participated in a business venture.

(b) Self-sufficiency: How far a household depends on and develops its own resources is important. Such a household, if also enterprising and open to new ideas will be more likely to be eager to acquire means to assimilate new innovations and even modify them.

Selected indicators were:

(1) participation of household members in building their own home and furniture;

(2) the type and number of hand tools they owned;

(3) their self-sufficiency in food supplies. Because most rural people (certainly all our case study households) have available agricultural land on which they may grow much of their food supplies, we have allocated a 1.5 weighting to the score for self-sufficiency in food supplies;

(4) how independent they were in yaqona (traditional drink) supplies; this was given a 0.5 weighting for growing their own yaqona would take up much land, which some householders may not be able to spare;

(5) whether they owned or shared toilet facilities; and,

(6) whether their cash income was earned entirely from within the household.

(c) Desire for material comforts: As it is only possible to assess what is tangible, indicators for better living standards were inevitably those that bring about materialistic comforts.

Indicators used were:

(1) the type of house a household lives in;

(2) the type, number and variety of furniture they have;

(3) the type and number of household appliances; and,

Table 55. Social indicators of the desire for change and improvement.

Enterprise	
Vakagalala	
Leasee	4
Part-time leasee	3
Traditional arrangement	2
Part-time traditional arrangement	1
None of the above	0
Private transport means	
For hire and/or own use	4
Own transport and "Kerekere" by others	3
Hired transport	1
None	0
Farming	
Each male adult has a garden and some livestock	4
Each male adult has a garden or some livestock	3
Shared ownership in home of garden and livestock	2
Shared with other homes	1
None	0
Sale of crops and livestock	
Either all crops or all livestock sold	4
Most (more than 50%) of either is sold	3
Some (less than 50%) of either is for sale	2
All for home needs except for occasional sales	1
All for home needs	0
Business (includes sale of handicrafts)	
Private ownership of one or more businesses	4
Partnership	3
Office bearer of cooperative	2
Cooperative member	1
None of the above	0
Self-sufficiency	
Home and furniture	
Built own kitchen, toilet, and furniture	4
Build only some of above	3
Build only furniture	2
Helped with the building of above by others	1
Built by others	0
Tools	
Has more than three types of gardening tools and does not borrow	4
Has more than three types of gardening tools but also borrows	3
Has three gardening tools	2
Has one or two of above	1
Has none	0
Food supplies (weighting is 1.5)	
No food (except sugar and tea) purchased from shop during survey	4
Meal items purchased only occasionally (less than three times a week from the shop)	3
At least three meals a week, and up to one-third of a week's meals contain purchased items	2
More than one-third of a week's meals contain purchased items	1
All meals during the week contain some purchased items	0
Yaqona (weighting is 0.5)	
Yaqona from own garden plus own crusher	4
Borrowed crusher	3
Buys yaqona but owns crusher	2
Both yaqona and crusher belong to somebody else	0
Toilet facilities (shower room, toilet)	
Own toilet facilities	4
One or the other is shared	3
Both shared	2
Owns one but has none of the other	1
Has none	0
Sources of income	
Solely from within household (excluding remittances from members of household working in urban areas)	4
Portion only from within	3
All from without but household members	2
All from without and nonfamily members	1
Desire for material comforts	
House type	
Block or all wooden	4
Wood and other materials	3
Good burė	2
Bure with iron	1
Bure in poor condition	0
Furniture	
Beds, tables and chairs, cupboard	3
Cupboard, bed plus one more piece of furniture	2
One or two pieces only	1
None	0
Appliances in home	
Refrigerator plus others	4
Sewing machine, kerosene cooker, gas lamp and others	3
Sewing machine, kerosene cooker, and gas lamp	2
Only one or two of the above	1
Toilet type	
Flush and water seal	4
Pit latrine	2
None	0

(4) the types of toilet facilities they provide for themselves.

The scores allocated appear in Table 55. All scores were given equal weighting. Scores obtained under each of the three major categories (Enterprise, Self-Sufficiency and Materialistic Comforts) were added together, and the average score calculated. Thus each household ultimately had three separate scores each in the range 0–4.

Results

The results of our assessment are set out in Fig. 20 a, b, c. The seven farmers are assumed to represent the types that would be open to and adopt innovations readily. They serve as reference levels with which to compare village populations covered in the case studies. The scatter diagrams of Fig. 20 show that farmers display much greater enterprise than villagers but are not different overall in self-sufficiency and materialistic comforts.

Villagers and farmers are all dependent on the land for their living. While farmers obtain a mean $16 304 per household gross annual cash income from utilization of their land, villagers obtain only a mean $543 per household gross annual cash income. Villagers, however, obtain comparable, sometimes better, material comforts and self-sufficiency than farmers. Most of the villager's gross cash income is net, but most of the farmers we surveyed are committed to heavy loan repayments and expenditures such as for weedicides, fertilizers, etc.

Table 56 shows the daily food consumption of our case study populations and the sources of the various food items. These show that villagers are more self-sufficient

Table 56. Daily food consumption per person in our case study populations.[a]

		Quantities consumed per day					
Case study	Food sources	Starchy food weight (kg)	Protein food (kg)	Fruit and vegetables (kg)	Sugar (kg)	Total weight (kg)	% of each
Natia	Subsistence	1.2		0.1		1.3	68
	Marine		0.2			0.2	10
	Cash	0.3			0.1	0.4	22
Total		1.5	0.2	0.1	0.1	1.9	100
Yaroi	Subsistence	0.9		0.2		1.1	44
	Marine		1.0			1.0	40
	Cash	0.1	0.1		0.2	0.4	16
Total		1.0	1.1	0.2	0.2	2.5	100
Nacamaki	Subsistence	0.8		0.2		1.0	71
	Marine		0.15			0.15	11
	Cash	0.1	0.05		0.1	0.25	18
Total		0.9	0.20	0.2	0.1	1.40	100
Naqelewai	Subsistence	1.0		0.1		1.1	80
	Forest/river		0.2			0.2	14
	Cash	0.07	0.01		0.2	0.1	6
Total		1.07	0.21	0.1	0.2	1.4	100
Isolated farmers	Subsistence	0.1		0.1		0.2	15
	Cash	0.6	0.3		0.2	1.1	85
	Other	Negligible (e.g., prawns from river)					
Total		0.7	0.3	0.1	0.2	1.3	100

[a] Measurements that were taken were accurate to 0.01 kg, but results have been rounded to the first decimal point.

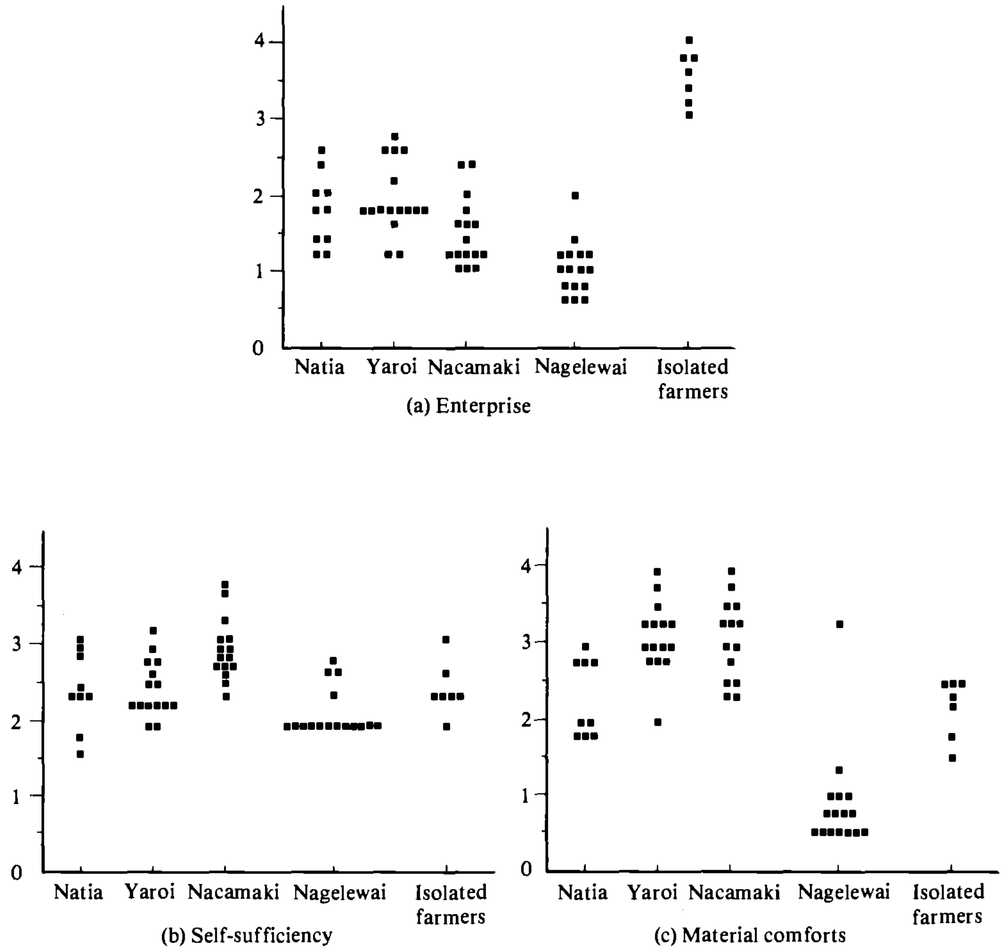


Fig. 20. *Social indicator scores for the case studies.*

in food items. They obtain from 78% to 94% of their daily food consumption from subsistence and forest and marine sources, while only 6–22% is obtained through cash expenditure. On the other hand our farmers purchase 85% of their daily food requirements.

Bayliss-Smith (1977) claimed that "the economy of Nacamaki seems to function with considerable efficiency." The observation is true, in at least three of our case study villages, of significant self-sufficiency and adequate material comforts gained without undue exertion in the cash economy. To this extent we support Bayliss-Smith's claim.

It is not surprising that to outsiders, villagers appear to resist change, to be apathetic to development, to be conservative, and unwilling to increase contribution to the "net domestic product" of the country. They achieve what is to them an adequate standard of living without too much dependence on the cash sector.

Significantly, however, and as observed by Bayliss-Smith, the people of Nacamaki appear to be very responsive to economic forces. Their responses have been rational and geared both toward maximizing security and increasing cash receipts. Their aspirations rise with increasing contact with the outside world. In our analysis we found the presence of enterprise, aspirations, and self-reliance in all the case studies covered. Indeed, as shown in the tables and figures referred to in this section, they are quite significant in a number of cases. These, coupled with Bayliss-Smith's conclusion that the ready acceptance of the fact that material aspiration can only be satisfied through entry into the cash economy, augur well for a systematic program of encouraging rural economic activity aimed at enhancing the standard of living of the rural population.

Appendix 1

Contributors to Field Work

Senior Home Economics Students

Asaeli Ciba Sokovagone
Jieni Taoba
Luisa Zoing
Seini Seniloli
Villisi Diloi

Other Student Helpers

Ganeshan Rao
Lasarusa Waisele
Sakeasi N. Kaloumaira
Tevita Nauluca

Temporary Graduate Helpers

Jenny Baines
Luisa Vatucicila

Chiefs at our Case Study Villages

Vilikesa Ravisa (Natia, Viwa)
Tui Matuku (Yaroi, Matuku)
Tuina (Nacamaki, Koro)
Ratu Sakiusa (Naqelewai)

Other Villagers

Suliano Matanakiwai (Nacamaki)
Ilami (Natia)
Tomasi (Yaroi)

Other Temporary Helpers from the Civil Service

Jojivini Levaci, School Teacher
Graham Teskey, Central Planning Office

Officers of the Ministry for Rural Development helped in arrangements for our various trips to villages, while officers of the Ministry for Agriculture helped select our case study farms. Many of our field instruments were kindly lent to us by the School of Natural Resources. We are also grateful for the loan of a hand anemometer and wet and dry bulb thermometers from Mr Pita Rakoroi of the Fiji Meteorological Services.

Appendix 2

Allowances for Depreciation and Improvements (Amendment) Instructions, 1976[1]

In exercise of the powers conferred upon me by sub-paragraph (i) of paragraph (*a*) of subsection (1) of section 21 of the Income Tax Act, 1974, I have issued the following General Instructions to the Commissioner of Inland Revenue:—

1. These Instructions may be cited as the "Allowances for Depreciation and Improvements (Amendment) Instructions, 1976," and shall be deemed to have come into force on the 1st day of January, 1976.

2. The Second Schedule to the Allowances for Depreciation and Improvements Instructions published in reprint form at page 147 of the 1972 Reprints of the Laws of Fiji is amended by inserting the following paragraphs immediately after paragraph 3:—

"3A. Allowances for Capital Expenditure Relating to Fuel Economy and Alternative Sources of Energy

(*a*) By Instructions to the Commissioner and subject to such conditions as he thinks fit, the Minister, in order to encourage economies in the use of fuel oil and its derivatives, may, on application by a taxpayer, approve the following allowances for depreciation in respect of capital expenditure:—

(i) an allowance of 100 per cent. of the expenditure incurred in the adaptation of buildings, plant and machinery presently employed in a trade or business where such expenditure is considered to be expedient for the purpose of reducing the consumption of electricity or fuel oil or its derivatives, such allowance to be in substitution for any other allowance for depreciation; or

(ii) an initial allowance of 50 per cent. of the expenditure considered to be expedient for the purpose of economising in the consumption of electricity and incurred upon plant and machinery purchased to replace plant and machinery presently used in any trade or business in substitution for the initial allowance of 20 per cent. referred to in paragraph 2 of this Schedule to these Instructions; or

(iii) either—

(*aa*) a fuel economy investment allowance of up to 40 per cent. of the expenditure incurred upon plant and machinery purchased to replace plant and machinery used in a trade or business, and using an alternative energy to electricity or fuel oil and its derivatives; or

(*bb*) a fuel economy investment allowance of 40 per cent, of the expenditure incurred upon an asset used in a trade or business which generates energy from a source of energy which is indigenous to and is produced in Fiji:

Provided that the fuel economy investment allowance, which shall be in addition to the initial and annual allowances provided under any other paragraph of these Instructions, shall not be approved unless the expenditure is deemed to be expedient for the economic benefit of Fiji and also to be capable of achieving substantial savings in foreign exchange.

[1] Excerpt from the Fiji Royal Gazette Supplement, 30 July, No. 29, Legal Notice No. 99, Income Tax Act, 1974 (No. 6 of 1974).

(*b*) (i) The depreciation and initial allowances referred to in the last preceding subparagraph shall be deducted by the taxpayer from the total income for the accounting year in which the expenditure is incurred but the capital value of any asset upon which such expenditure is incurred shall be written down accordingly.

(ii) The fuel economy investment allowance shall not be deducted in calculating the written down value of any asset in respect of which the allowance has been granted:

Provided that in the event of a sale of any such asset within 5 years of the end of the accounting year in which the asset was purchased the amount of the fuel economy investment allowance shall be added back to the income of the trade or business for the year in which such asset is sold.

(iii) It is hereby declared that for the purposes of paragraph (*a*) of subsection (1) of section 21 of the Income Tax Act, 1974 any allowances approved under the provisions of this paragraph other than the fuel economy investment allowance shall be deemed to be depreciation.

Appendix 3

(a) Solar Energy Resources[1]

Average cloud cover (%) over selected 2.5 dbg. squares.

Area	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Tarawa	54	51	50	45	43	44	44	40	43	41	41	48	45
Ocean Is.	56	53	47	46	42	42	43	41	42	42	43	52	50
Nui	59	57	54	51	48	49	46	49	49	48	48	54	51
Funafuti	61	61	56	54	50	51	47	51	51	54	54	58	54
Toxelau Is.	59	56	51	50	49	47	44	47	48	46	53	57	51
Penbhyn	50	49	46	46	45	46	40	41	43	42	47	50	45
Samoa	59	56	52	53	49	46	49	51	48	54	52	59	52
Yasawa	55	56	55	51	53	52	54	51	51	56	53	55	54
Vanua Levu	57	59	55	53	53	53	54	52	52	57	55	59	55
SW Viti Levu	54	54	56	52	53	56	59	52	53	57	52	55	54
Kandavu	54	55	57	54	55	56	60	53	55	58	55	60	56
Lau	56	53	56	53	55	55	57	54	55	60	53	58	55
Nukualofa	55	53	57	54	56	56	58	56	59	59	52	56	56
Aitutaki	53	57	50	48	51	48	53	55	50	55	56	53	52
Rarotonga	57	56	52	53	58	53	55	59	57	56	57	57	56

Average sunshine (hours per day).

Area	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Nandi	6.7	6.4	5.8	6.5	6.7	6.9	7.0	7.8	7.1	7.2	7.3	7.0	6.9
Lautoka	6.7	6.5	6.1	6.7	6.8	6.5	6.9	7.4	7.0	6.9	7.0	6.9	6.8
Lambasa	5.0	5.1	5.3	5.7	6.3	6.3	6.4	7.1	6.3	5.8	5.7	5.5	5.9
Singatoka	5.5	5.2	4.7	4.6	4.9	4.6	4.9	5.6	5.2	5.7	5.9	5.9	5.2
Seangangga	5.1	4.4	4.2	4.8	5.6	5.7	5.5	6.6	5.2	5.8	4.9	4.5	5.2
Suva	5.8	5.6	5.2	5.1	4.9	4.5	4.3	5.0	4.4	5.0	5.7	6.1	5.1
Tamanoa	5.9	5.8	4.6	5.2	4.7	3.8	3.9	5.2	4.3	5.3	5.3	4.7	4.9
Koronivia	5.5	5.1	4.4	4.7	4.2	4.0	3.7	4.8	4.1	5.0	4.8	4.4	4.6
Dombuilevu	4.6	4.4	3.8	4.1	3.8	4.2	4.0	5.0	4.1	4.1	4.2	3.6	4.1

Average sunshine (approximate percentage of possible).

Area	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Nandi	54	52	50	58	62	66	66	71	62	60	59	55	60
Lautoka	54	53	52	60	63	62	65	67	61	57	56	54	59
Lambasa	40	42	39	61	58	60	60	65	55	48	46	43	51
Singatoka	44	43	40	41	45	44	46	51	45	47	48	46	45
Seangangga	40	36	36	43	52	54	52	60	45	48	40	35	45
Suva	46	46	44	46	45	43	41	45	38	42	46	48	44
Tamanoa	47	48	39	46	44	36	37	47	37	44	43	37	43
Koronivia	44	41	38	42	39	38	35	44	36	42	39	35	40
Dombuilevu	37	36	32	37	35	40	38	45	36	34	34	28	36

[1] All tables are by J.F. Gabites, Director of Meteorological Service Fiji.

Average solar radiation at Nandi (MJm^{-2} per day).

Area	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Nandi	20.7	20.2	18.0	16.4	15.0	13.8	14.7	17.2	19.0	20.8	21.5	21.7	18.2

(b) Fiji Meteorological Service Reports

Ambient Air Temperatures in Fiji

The following table is intended as a general guide to the range of ambient air temperatures for which equipment and structures in Fiji need to be designed.

The table shows:

(a) Lowest air temperature recorded (°C).
(b) Mean daily minimum for the coldest month (July or August).
(c) Mean daily maximum for the warmest month (January or February).
(d) Highest air temprature recorded (°C).

Range of ambient air temperatures.

	a	b	c	d
Viti Levu				
Nandi (Airport)	11	18	31	38
Lautoka (Sugar Mill)	13	20	31	36
Mba (Rarawai Sugar Mill)	10	17	33	38
Rakiraki (Penang Sugar Mill)	12	20	31	37
Nausori (Airport)	12	19	31	34
Suva (Lauthala Bay)	15	20	31	35
Suva (Government House)	13	20	30	37
Singatoka (Nathothelevu Research Station)	10	17	31	38
Nandarivatu (835 m)	4	14	26	33
Kore-O (945 m)	8	14	25	30
Vanua Levu				
Lambasa (Airport)	10	18	31	35
Lambasa (Sugar Mill)	12	19	31	37
Savusavu (Airport)	15	26	30	34
Nambouwalu	17	22	30	34
Outlying Islands				
Rotuma	18	24	30	36
Yasawa-i-Rara	14	22	30	34
Taveuni (Matei)	16	22	30	34
Ovalau (Lovuka)	16	21	30	34
Kandavu (Vunisea)	13	20	30	35
Matuku	14	21	30	34
Lakemba	15	21	30	37
Ono-i-Lau	15	20	29	36

In most places daily maximum temperatures average 30–31°C in the hottest month, but in a few sheltered inland places may average 32–34°C. A temperature of 38°C has been recorded.

Daily minimum temperatures average 18–21°C in the coldest month in most places but a few degrees lower in inland valleys and at high levels.

Sunshine

The following tables show the average sunshine at stations in Fiji. The first table shows the average number of hours per day of bright sunshine. The second table shows the relative proportion of bright sunshine as a percentage of that possible if the sun were unobscured all day.

Average sunshine (hours per day).

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Nandi	6.7	6.4	5.8	6.5	6.7	6.9	7.0	7.8	7.1	7.2	7.3	7.0	6.9
Lautoka	6.7	6.5	6.1	6.7	6.8	6.5	6.9	7.4	7.0	6.9	7.0	6.9	6.8
Lambasa	5.0	5.1	5.3	5.7	6.3	6.3	6.4	7.1	6.3	5.8	5.7	5.5	5.9
Singatoka	5.5	5.2	4.7	4.6	4.9	4.6	4.9	5.6	5.2	5.7	5.9	5.9	5.2
Seanggangga	5.1	4.4	4.2	4.8	5.6	5.7	5.5	6.6	5.2	5.8	4.9	4.5	5.2
Suva	5.8	5.6	5.2	5.1	4.9	4.5	4.3	5.0	4.4	5.0	5.7	6.1	5.1
Tamanoa	5.9	5.8	4.6	5.2	4.7	3.8	3.9	5.2	4.3	5.3	5.3	4.7	4.9
Koronivia	5.5	5.1	4.4	4.7	4.2	4.0	3.7	4.8	4.1	5.0	4.8	4.4	4.6
Dombuilevu	4.6	4.4	3.8	4.1	3.8	4.2	4.0	5.0	4.1	4.1	4.2	3.6	4.1

Average sunshine (approximate percentage of possible).

Nandi	54	52	50	58	62	66	66	71	62	60	59	55	60
Lautoka	54	53	52	60	63	62	65	67	61	57	56	54	59
Lambasa	40	42	39	61	58	60	60	65	55	48	46	43	51
Singatoka	44	43	40	41	45	44	46	51	45	47	48	46	45
Seanggangga	40	36	36	43	52	54	52	60	45	48	40	35	45
Suva	46	46	44	46	45	43	41	45	38	42	46	48	44
Tamanoa	47	48	39	46	44	36	37	47	37	44	43	37	43
Koronivia	44	41	38	42	39	38	35	44	36	42	39	35	40
Dombuilevu	37	36	32	37	35	40	38	45	36	34	34	28	36

Relative Humidity

The following table shows the average relative humidity (percent) at midnight, 6 am, noon, and 6 pm, at a selection of stations in Fiji. They are: two stations that are typical of the drier northwestern sides and the wetter southeastern sides respectively of the larger islands (Viti Levu, Vanua Levu, Taveuni), namely: Nandi and Suva; three stations on small islands in the extreme north, centre, and extreme south of Fiji namely: Rotuma, Lakemba and Ono-i-Lau.

Average relative humidity (%).

Place	Time	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sept	Oct	Nov	Dec	Year
Nandi	0000	90	91	93	92	89	89	86	85	85	84	86	88	88
	0600	92	93	94	93	93	91	89	88	88	87	88	90	90
	1200	68	70	71	69	64	63	61	59	61	62	63	65	65
	1800	78	80	82	81	78	77	73	71	72	73	74	76	76
Suva	0000	90	90	92	90	88	87	85	85	86	86	87	88	88
	0600	92	93	93	92	92	90	88	87	88	87	85	90	90
	1200	77	77	77	77	75	76	74	73	75	74	79	78	76
	1800	82	83	84	84	82	82	79	79	81	81	81	81	81
Rotuma	0000	88	89	89	88	88	87	85	85	86	87	88	88	87
	0600	89	90	90	89	89	88	85	86	86	88	88	89	88
	1200	78	79	79	78	78	78	76	76	76	77	78	78	78
	1800	82	83	84	84	85	84	82	82	83	83	83	82	83
Lakemba	0000	88	88	89	88	84	84	82	81	84	83	83	84	85
	0600	89	90	91	89	86	85	84	82	85	83	85	86	86
	1200	76	75	77	75	73	73	71	71	72	72	72	73	73
	1800	81	81	83	83	81	81	79	78	80	79	80	79	80
Ono-i-Lau	0000	84	85	86	85	80	79	77	80	80	81	82	83	82
	0600	85	87	88	86	81	81	78	79	81	82	83	84	83
	1200	77	79	81	79	73	74	70	70	71	72	73	76	74
	1800	82	83	85	83	79	79	76	78	79	80	80	82	81

Appendix 4

Guideline to Biogas Production and Consumption

The following table provides very rough guidelines to the gas production and consumption one might expect in actual field conditions in the Pacific Islands based on 5 ft^3 of gas per pound of volatile solids and consumption at 2–3 in. of water pressure (1 atmosphere = 33.9 feet of water). One imperial gallon of petrol is equivalent to about 250 ft^3 of biogas, and 100 ft^3 of volume = 2.8 m^3 = 625 imperial gallons. A small (1–10 BHP) petrol engine will consume about 16 ft^3 of biogas per hour per rated horsepower or 19 ft^3 of gas/h/actual horsepower (due to power loss when using biogas), 1 kWh of electricity will require 50–60 ft^3 of gas at 2–4 in water pressure.

Biogas production and consumption.

Biogas production			Biogas consumption		
Animal	Weight (pounds)	Biogas (ft^3/day)	Use	Conditions	Consumption
Dairy	1600	69	Cooking	2 in ring	11.5 ft^3/h
Dairy heifer	1000	37		4 in ring	16.5 ft^3/h
Beef heifer	1000	29		6 in ring	22.5 ft^3/h
Beef stocker	500	20		Person per day	12–15 ft^3
Hog	500	8		Family of 4–6	
Hog	200	5		per day	49–72 ft^3
Hog	100	2.5			
Weiner	15	0.37	Lighting	1 mantle	3 ft^3/h
Hen (broiler)	4	0.25		2 mantles	5 ft^3/h
Hen (laying)	4	0.20		3 mantles	7 ft^3/h
Human (including urine)	150	1.25	Refrigerator	1 ft^3	1.2 ft^3/h

[1] Figures extracted from *Energy primer, solar, water, wind and biofuels*, 1974. Menlo Park, California, Portola Institute.

Appendix 5

Valuation of the Effluent from Digesters as a Fertilizer

1. Taiganides and Hazen (1966) showed that 10 × 100 lb hogs produce: per day, 0.500 lb N; 0.200 lb P; and 0.480 lb K; per year, 84.09 kg N; 50 kg P; and 78.18 kg K.

2. Hobson and Shaw (1973) showed that digested sludge of 10 × 100 lb hogs contain equivalent of per year 100.908 kg N.

3. Rudolfs (1928) showed total solids reduced by 25% after digestion.

4. Fiji prices of NPK (in 13:13:21 mixture) are 23.86¢/kg for N and P (bulk price), and 24.17¢/kg for K (bulk price) (from Morris Hedstrom, Agriculture Section).

Therefore, the equivalent price of pig dung (10 × 100 lb hogs) for undigested is an annual output valued at N, \$20.06; P, \$11.93; and K, \$18.90. For digested only N increases to a value of \$24.08, P and K remain unaltered. The increase in value is, therefore, \$4.02, i.e., 20%, after a 25% loss of solids the increase in value is \$3.02, i.e., 15%.

5. Baines (1970) reports the following fertilizer effects on yields (mean yield figures indicate a 15% increase in value of digested sludge over farmyard manure as fertilizer).

Effect of fertilizer on yields.

Fertilizer	Yield potatoes	Grass	Mean yield of two crops
Balanced NPK	100	100	100
Farmyard manure	106	91	98.5
Digested sludge	112	115	113.5
PK and farmyard manure	133	107	
PK and digested sludge	192	130	

Appendix 6

Analysis of Digesters at Present Loading and Usage

Table 1a. Capital costs of Digester 1 (7.5 m^3). (Built in 1972, prices converted to 1977 values.)[a]

	Capital costs ($)	Foreign (%)	Local (%)	1977 costs ($) at different foreign exchange shadow price factors 1.0	1.2	1.4
Digester						
(1972)	610					
(1977)	1080	49	(51)	529	635	741
				(551)	(551)	(551)
Gas Cover						
(1972)	210					
(1977)	397	58	(42)	230	276	322
				(167)	(167)	(167)
Pipes						
Plastic — sewage and gas						
(1972)	60					
(1977)	97	52	(48)	50	60	70
				(47)	(47)	(47)
Labour						
Unskilled — agricultural labour rates						
(1972)	120					
(1977)	211			0	0	0
Skilled — supervisory						
(1977)	65	—	(100)	(65)	(65)	(65)
Appliances						
Cooker						
(1972)	22					
(1977)	34	56	(44)	19	23	27
				(15)	(15)	(15)
Total initial capital outlay				1673	1837	2003
Cost of replacement of gas cover and cooker every 10 years at different discount rates						
5% discount rate				427	476	553
7.5% discount rate				310	346	382
10% discount rate				230	256	282

[a] The analysis of Digester 1 is based on a family of nine. Conversion factors taken from Fiji's "Economic Statistics," are: digester $(1.121)^5$, gas cover $(1.360)^5$, plumbing ware $(1.10)^5$, unskilled labour $(1.12)^5$, and appliances $(1.109)^5$.

Table 1b. Running costs and annual benefits of Digester 1 (7.5 m^3).

	Running costs and annual benefits ($)	Foreign (%)	Local (%)	1977 costs ($) at different foreign exchange shadow price factors		
				1.0	1.2	1.4
Unskilled labour for cleaning digester and contingencies (3 days)	12	0	(100)	0	0	0
Unskilled labour for washing pens daily (10 min/day)	28	0	(100)	0	0	0
Paint and rust guard	20	76	(24)	15 (5)	18 (5)	21 (5)
Total running costs				20	23	26
Benefits						
Kerosene for 48.5 weeks at 19.6¢/litre	150	71	(29)	107 (43)	128 (43)	149 (43)
Reduced depreciation on cooker (Hong Kong wick)	2	56	(44)	1 (1)	1 (1)	1 (1)
Total benefits fuel only				152	173	194
Fertilizer benefit (saving foreign exchange)	12	0	(100)	(12)	(14)	(17)
Net benefit per year						
Fuel only				132	150	168
Fuel and fertilizer				144	164	185

Table 1c. Net present value (NPV) and benefit/cost (B/C) ratio of Digester 1 (7.5 m³).

		Foreign exchange shadow price factors											
		1.0				1.2				1.4			
		Fuel		Fuel and fertilizer		Fuel		Fuel and fertilizer		Fuel		Fuel and fertilizer	
Discount rates (%)	Capital subsidy rates (%)	NPV($)	B/C	NPV($)	B/C	NPV($)	B/C	NPV($)	B/C	NPV($)	B/C	NPV($)	B/C
	0	−71	−0.3	114	0.06	93	0.05	208	0.1	26	0.02	188	0.08
5	25	456	0.29	640	0.41	571	0.34	786	0.46	665	0.35	927	0.49
	50	981	0.94	1166	1.12	1151	1.0	1366	1.19	1306	1.03	1568	1.23
	0	−424	−0.2	−282	−0.14	−411	−0.18	−244	−0.11	−400	−0.16	−200	−0.08
7.5	25	72	0.05	214	0.15	142	0.09	307	0.19	203	0.11	436	0.23
	50	570	0.58	712	0.72	682	0.63	847	0.78	794	0.67	995	0.84
	0	−630	−0.33	−546	−0.28	−679	−0.32	−547	−0.26	−701	−0.30	−541	−0.23
10	25	−183	−0.12	−70	−0.04	−156	−0.09	−24	−0.01	−130	−0.07	30	+0.02
	50	295	0.29	418	0.43	369	0.36	501	0.48	443	0.39	604	0.53

Table 2a. Capital costs of Digester 2 (5 m^3). (Built in 1975, prices converted to 1977 values.)[a]

	Capital costs ($)	Foreign (%)	Local (%)	1977 costs ($) at different foreign exchange shadow price factors 1.0	1.2	1.4
Digester						
(1975)	652					
(1977)	808	49	(51)	396	475	554
				(412)	(412)	(412)
Gas Cover						
(1975)	297					
(1977)	549	58	(42)	318	382	445
				(231)	(231)	(231)
Pipes						
Plastic — sewage and gas						
(1975)	170					
(1977)	206	52	(48)	107	128	150
				(99)	(99)	(99)
Labour						
Unskilled — agricultural labour rates						
(1975)	576					
(1977)	720			0	0	0
Skilled — supervisory						
(1977)	65	0	(100)	(65)	(65)	(65)
Appliances						
Cooker						
(1975)	120	51	(49)	73	88	102
				(70)	(70)	(70)
Miscellaneous						
(1975)	34					
(1977)	40	51	(49)	20	24	28
				(20)	(20)	(20)
Total initial capital outlay				1811	1994	2176
Cost of replacement of gas cover and cooker every 10 years at different discount rates						
5% discount rate				684	762	838
7.5% discount rate				497	554	610
10% discount rate				368	410	451

[a] Conversion factors taken from Fiji's "Economic Statistics" are digester $(1.114)^2$, gas cover $(1.360)^2$, plumbing ware $(1.09)^2$, unskilled labour $(1.12)^2$, and appliances $(1.09)^2$.

Table 2b. Running costs and annual benefits of Digester 2 (5 m^3).

	Running costs and annual benefits ($)	Foreign (%)	Local (%)	1977 costs ($) at different foreign exchange shadow price factors 1.0	1.2	1.4
Unskilled labour for cleaning digester and contingencies (3 days)	12			0	0	0
Unskilled labour for washing pens daily (10 min/day)	28			0	0	0
Paint and rust guard	20	76	(24)	15 (5)	18 (5)	21 (5)
Total running costs				20	23	26
Benefits						
Kerosene for 48.5 weeks at 19.6¢/litre	267	71	(29)	189 (78)	228 (78)	265 (78)
Reduced depreciation on cooker (Hong Kong wick)	2	56	(44)	1 (1)	1 (1)	1 (1)
Total benefits fuel only				269	308	346
Fertilizer benefit (saving foreign exchange)	21	0	(100)	(21)	(25)	(29)
Net benefit per year						
Fuel only				249	285	320
Fuel and fertilizer				270	310	349

Table 2c. Net present value (NPV) and benefit/cost (B/C) ratio of Digester 2 (5 m^3).

		Foreign exchange shadow price factors											
		1.0				1.2				1.4			
		Fuel		Fuel and fertilizer		Fuel		Fuel and fertilizer		Fuel		Fuel and fertilizer	
Discount rates (%)	Capital subsidy rates (%)	NPV($)	B/C	NPV($)	B/C	NPV($)	B/C	NPV($)	B/C	NPV($)	B/C	NPV($)	B/C
5	0	1332	0.53	1655	0.66	1625	0.59	2009	0.73	1905	0.63	2351	0.78
	25	1956	0.78	2279	0.91	2324	0.84	2708	0.98	2658	0.88	3104	1.03
	50	2580	1.03	2903	1.16	3023	1.10	3407	1.24	3411	1.13	3857	1.28
7.5	0	653	0.28	901	0.39	818	0.32	1113	0.44	993	0.36	1336	0.48
	25	1225	0.54	1473	0.64	1455	0.57	1750	0.69	1689	0.61	2032	0.73
	50	1797	0.78	2045	0.89	2092	0.82	2387	0.94	2385	0.86	2728	0.98
10	0	168	0.08	366	0.17	282	0.12	518	0.22	389	0.15	660	0.25
	25	713	0.33	911	0.42	884	0.37	1120	0.47	1046	0.40	1317	0.50
	50	1258	0.58	1456	0.67	1486	0.62	1722	0.72	1435	0.55	1974	0.75

Table 3a. Capital costs of Digester 3(A) and 4(B) (both 1.5 m^3). (Digester 3 was built in 1971 and Digester 4 was built in 1975.)[a]

	Capital costs ($)	Foreign (%)	Local (%)	1977 costs ($) at different foreign exchange shadow price factors 1.0	1.2	1.4
Digester						
A (1971)	200					
B (1975)	222					
(1977)	275	49	(51)	135	162	189
				(140)	(140)	(140)
Gas Cover						
A (1971)	Not known					
B (1975)	218					
(1977)	403	58	(42)	234	281	328
				(169)	(169)	(169)
Pipes						
Plastic — sewage and gas						
A (1971)	Not known					
B (1975)	93					
(1977)	113	52	(48)	59	71	83
				(54)	(54)	(54)
Labour						
Unskilled — agricultural labour rates						
(1977)	180			0	0	0
Skilled — supervisory						
(1977)	65	0	(100)	(65)	(65)	(65)
Appliances						
A (1971)	8					
B (1975)	30	51	(49)	18	22	25
(1977)	36			(18)	(18)	(18)
Miscellaneous						
A (1971)	Not known					
B (1975)	26					
(1977)	31	51	(49)	16	19	22
				(15)	(15)	(15)
Total initial capital outlay				923	1016	1108
Cost of replacement of gas cover and cooker every 10 years at different discount rates						
5% discount rate				434	484	534
7.5% discount rate				315	352	388
10% discount rate				234	260	288

[a] The owner of Digester 3 did not know the costs incurred for his digester, but it is the same size as Digester 4. The analysis of Digester 3 is based on a family of five.

Table 3b. Running costs and annual benefits of Digester 3 (1.5 m³).

	Running costs and annual benefits ($)	Foreign (%)	Local (%)	1977 costs ($) at different foreign exchange shadow price factors 1.0	1.2	1.4
Unskilled labour for cleaning digester and contingencies (3 days)	12			0	0	0
Unskilled labour for washing pens daily (5 min/day)	14			0	0	0
Paint and rust guard	10	76	(24)	8 (2)	10 (2)	11 (2)
Total running costs				10	12	13
Benefits						
Kerosene for 48.5 weeks at 19.6¢/litre	83	71	(29)	59 (24)	70 (24)	83 (24)
Benzine (unleaded petrol) for 48.5 weeks at 33.6¢/litre	6	71	(29)	4 (2)	5 (2)	6 (2)
Reduced depreciation on cooker (Hong Kong kerosene cooker)	2	56	(44)	1 (1)	1 (1)	1 (1)
Reduced depreciation on benzine lamp	1	56	(44)	0.5 (0.5)	0.6 (0.5)	0.7 (0.5)
Total benefits fuel only				92	104	118
Fertilizer benefit (saving foreign exchange)	6	0	(100)	6	7	7
Net benefit per year						
Fuel only				82	92	105
Fuel and fertilizer				88	99	113

Table 3c. Net present value (NPV) and benefit/cost (B/C) ratio of Digester 3 (1.5 m^3).

Discount rates (%)	Capital subsidy rates (%)	Foreign exchange shadow price factors											
		1.0				1.2				1.4			
		Fuel		Fuel and fertilizer		Fuel		Fuel and fertilizer		Fuel		Fuel and fertilizer	
		NPV($)	B/C	NPV($)	B/C	NPV($)	B/C	NPV($)	B/C	NPV($)	B/C	NPV($)	B/C
	0	−97	−0.07	− 4	−0.003	− 86	−0.06	6	0.004	− 28	−0.02	64	0.04
5	25	242	0.23	335	0.33	289	0.26	381	0.34	383	0.31	475	0.39
	50	582	0.86	675	0.99	664	0.89	756	1.01	793	0.97	885	1.08
	0	−270	−0.22	−199	−0.16	−281	−0.21	−211	−0.15	−256	−0.17	−185	−0.12
7.5	25	39	0.04	110	0.12	61	0.06	131	0.13	118	0.11	189	0.17
	50	349	0.56	420	0.68	403	0.60	473	1.69	492	0.66	563	0.75
	0	−383	−0.33	−327	−0.28	−409	−0.32	−352	−0.27	−406	−0.29	−350	−0.25
10	25	− 95	−0.11	− 38	−0.04	− 90	−0.09	− 33	−0.03	− 57	−0.05	− 1	−0.00
	50	+195	0.34	252	0.44	229	0.36	286	0.45	292	0.42	348	0.50

Table 4a. Annual benefits of Digester 4 (1.5 m^3).[a]

	Annual benefits ($)	Foreign (%)	Local (%)	1977 costs ($) at different foreign exchange shadow price factors 1.0	1.2	1.4
Benefits						
Kerosene for 48.5 weeks at 19.6¢/litre for 2 days/week	14	71	(29)	10 (4)	12 (4)	14 (4)
Reduced depreciation on cooker (Hong Kong kerosine cooker)	0.57			—	—	—
Total benefits fuel only				14	16	18
Fertilizer benefit (saving foreign exchange)	2	0	(100)	(2)	(2)	(3)
Net benefit per year						
Fuel only				4	4	5
Fuel and fertilizer				6	6	8

[a] The capital costs and running costs for Digester 4 are the same as for Digester 3. The analysis of Digester 4 is based on a family of six.

Table 4b. Net present value (NPV) and benefit/cost (B/C) ratio of Digester 4 (1.5 m^3).[a]

		Foreign exchange shadow price factors											
		1.0				1.2				1.4			
		Fuel		Fuel and fertilizer		Fuel		Fuel and fertilizer		Fuel		Fuel and fertilizer	
Discount rates (%)	Capital subsidy rates (%)	NPV ($)	B/C	NPV ($)	B/C	NPV ($)	B/C	NPV ($)	B/C	NPV ($)	B/C	NPV ($)	B/C
5	0	−1296	−0.95	−1265	−0.93	−1439	−0.96	−1408	−0.94	−1565	−0.95	−1534	−0.93
	25	− 957	−0.94	− 926	−0.91	−1064	−0.95	−1033	−0.92	−1155	−0.94	−1124	−0.91
	50	− 618	−0.91	− 587	−0.86	− 689	−0.91	− 658	−0.88	− 744	−0.91	− 713	−0.87
7.5	0	−1191	−0.96	−1167	−0.94	−1321	−0.97	−1297	−0.95	−1437	−0.96	−1413	−0.94
	25	− 882	−0.95	− 858	−0.92	− 979	−0.95	− 957	−0.93	−1060	−0.95	−1039	−0.93
	50	− 572	−0.92	− 548	−0.88	− 637	−0.93	− 613	−0.90	− 689	−0.92	− 665	−0.89
10	0	−1119	−0.97	−1100	−0.95	−1238	−0.97	−1219	−0.96	−1349	−0.97	−1330	−0.95
	25	− 830	−0.96	− 811	−0.93	− 919	−0.96	− 900	−0.94	−1000	−0.96	− 981	−0.94
	50	− 541	−0.93	− 522	−0.90	− 600	−0.94	− 581	−0.91	− 651	−0.93	− 632	−0.91

[a] Presently the fertilizer is not utilized at all.

Table 5a. Capital costs of Digester 5 (15 m³ neoprene bag digester). (Built in 1977, prices converted to 1977 values.)[a]

	Capital costs ($)	Foreign (%)	Local (%)	1977 costs ($) at different foreign exchange shadow price factors 1.0	1.2	1.4
Digester (neoprene bag) (1977)	814	56	(44)	456 (358)	547 (358)	638 (358)
Pipes (1977)	30	52	(48)	16 (14)	19 (14)	22 (14)
Labour						
Unskilled (1977)	48			0	0	0
Skilled (1977)	65	0	(100)	(65)	(65)	(65)
Appliances						
Stove (converted kerosene gas)	9	51	(49)	5 (4)	6 (4)	7 (4)
Total initial capital outlay				918	1013	1108

[a] The analysis of Digester 5 is based on a family of seven.

Table 5b. Running costs and annual benefits of Digester 5 (15 m³ neoprene bag digester).

	Running costs and annual benefits ($)	Foreign (%)	Local (%)	1977 costs ($) at different foreign exchange shadow price factors 1.0	1.2	1.4
Unskilled labour for cleaning and contingencies (3 days)	12			0	0	0
Unskilled labour for washing pens daily (5 min/day)	14			0	0	0
PVC glue and tape for mending leaks — negligible						
Total running costs				0	0	0
Benefits						
Kerosene for 48.5 weeks at 19.6¢/litre for 4 days/week	64	71	(29)	45 (19)	54 (19)	63 (19)
Reduced depreciation of kerosene cooker as standby	1	56	(44)	0.56 (0.44)	0.67 (0.44)	0.78 (0.44)
Total benefits fuel only				65	74	83
Fertilizer benefit (saving foreign exchange)	6	0	(100)	(6)	(7)	(8)
Net benefit per year						
Fuel only				65	74	83
Fuel and fertilizer				71	81	91

Table 5c. Net present value (NPV) and benefit/cost (B/C) ratio of Digester 5 (15 m^3 neoprene bag digester).

		Foreign exchange shadow price factors											
		1.0				1.2				1.4			
	Capital	Fuel		Fuel and fertilizer		Fuel		Fuel and fertilizer		Fuel		Fuel and fertilizer	
Discount rates (%)	subsidy rates (%)	NPV ($)	B/C	NPV ($)	B/C	NPV ($)	B/C	NPV ($)	B/C	NPV ($)	B/C	NPV ($)	B/C
	0	−416	−0.45	−369	−0.40	−442	−0.44	−388	−0.38	−467	−0.42	−405	−0.37
5	25	−187	−0.27	−140	−0.15	−189	−0.25	−135	−0.18	−190	−0.23	−128	−0.16
	50	42	0.09	89	0.10	64	0.13	118	0.24	87	0.16	149	0.27
	0	−472	−0.51	−431	−0.47	−505	−0.50	−457	−0.45	−538	−0.49	−483	−0.44
7.5	25	−243	−0.35	−202	−0.29	−252	−0.33	−204	−0.27	−261	−0.32	−206	−0.25
	50	− 14	−0.03	27	0.06	1	0.002	49	0.10	16	0.03	71	0.13
	0	−519	−0.56	−482	−0.52	−558	−0.55	−515	−0.51	−598	−0.54	−549	−0.50
10	25	−290	−0.42	−253	−0.36	−305	−0.40	−262	−0.35	−321	−0.39	−272	−0.33
	50	− 61	−0.13	− 24	−0.07	− 52	−0.10	− 9	−0.02	− 44	−0.08	5	0.01

Appendix 7

Analysis of Digesters at Full Loading and Different Levels of Use by an Average Rural Family

Table 1. Capital costs of digesters and appliances used in the analysis.

Discount rates (%)	Items	1977 costs ($) at different foreign exchange shadow price factors 1.0	1.2	1.4
5	Digester 1 (7.5 m^3)	2057	2265	2503
	Digester 2 (5 m^3)	1971	2178	2383
	Digester 3 and 4 (1.5 m^3)	1196	1328	1461
7.5	Digester 1	1974	2173	2374
	Digester 2	1859	2050	2242
	Digester 3 and 4	1112	1234	1358
10	Digester 1	1894	2083	2274
	Digester 2	1754	1936	2115
	Digester 3 and 4	1037	1151	1265
	Digester 5 (1977 costs of appliances)	918	1013	1108
	2 Burner cookers	40	44	49
	6 Gas lamps	42	47	52
	2 Gas lamps	14	16	17
	Refrigerator	505	562	618
	Extra pipes	30	33	36
5	2 Burner cookers	67	85	95
	6 Gas lamps	81	91	100
	2 Gas lamps	27	31	33
	Refrigerator	974	1084	1191
	Extra pipes	30	33	36
7.5	2 Burner cookers	69	76	84
	6 Gas lamps	72	81	89
	2 Gas lamps	24	28	29
	Refrigerator	869	967	1063
	Extra pipes	30	33	36
10	2 Burner cookers	61	67	78
	6 Gas lamps	64	72	80
	2 Gas lamps	21	25	26
	Refrigerator	774	862	947
	Pipes	30	33	36

NOTE: Gas cover and appliances replaced every 10 years.

Table 2. Capital costs of a 7.5 m^3 digester (30 year life) at different discount rates, subsidy rates, and foreign exchange shadow price factors with different end uses.

End use	Discount rate (%)	Subsidy rate (%)	Foreign exchange shadow price factors ($) 1.0	1.2	1.4
Cooking only	5	0	2124	2350	2598
		25	1593	1763	1949
		50	1062	1175	1299
	7.5	0	2043	2249	2458
		25	1532	1687	1844
		50	1022	1125	1229
	10	0	1955	2150	2352
		25	1466	1613	1764
		50	978	1075	1176
Cooking and lighting	5	0	2235	2471	2734
		25	1676	1853	2051
		50	1118	1236	1367
	7.5	0	2145	2363	2583
		25	1609	1772	1937
		50	1073	1182	1292
	10	0	2049	2255	2468
		25	1537	1691	1851
		50	1025	1128	1234
Cooking and refrigeration	5	0	2154	2383	2634
		25	1615	1787	1976
		50	1077	1192	1317
	7.5	0	2073	2282	2494
		25	1555	1712	1871
		50	1037	1141	1247
	10	0	1955	2183	2388
		25	1466	1637	1791
		50	978	1092	1194
Cooking, lighting, and refrigeration	5	0	2235	2475	2734
		25	1676	1856	2051
		50	1118	1238	1367
	7.5	0	2145	2363	2583
		25	1609	1773	1937
		50	1073	1182	1292
	10	0	2049	2255	2468
		25	1537	1691	1851
		50	1025	1128	1234

Table 3. Annual benefits of a 7.5 m^3 digester. Costs in 1977 values at different foreign exchange shadow price factors with different end uses.

End use	Foreign exchange shadow price factors ($) 1.0	1.2	1.4
Cooking only	100	114	128
Cooking and six lights	280	320	260
Cooking and refrigeration	155	177	199
Cooking, lighting, and refrigeration	335	383	429
Fertilizer benefit	45	54	63

Table 4. Net present value (NPV) and benefit/cost (B/C) ratio of a 7.5 m^3 digester.[a]

End use	Discount rate (%)	Subsidy rate (%)	Foreign exchange shadow price factors: 1.0 — Fuel — NPV ($)	B/C	1.0 — Fuel and fertilizer — NPV ($)	B/C	1.2 — Fuel — NPV ($)	B/C	1.2 — Fuel and fertilizer — NPV ($)	B/C	1.4 — Fuel — NPV ($)	B/C	1.4 — Fuel and fertilizer — NPV ($)	B/C
Cooking	5	0	− 587	−0.28	105	0.05	− 121	−0.06	708	0.3	− 78	−0.04	854	0.33
		25	− 56	−0.03	636	0.30	348	0.19	1177	0.67	433	0.21	1400	0.72
		50	475	0.45	1167	1.10	815	0.87	1646	1.40	945	0.92	1912	1.47
	7.5	0	− 862	−0.42	− 331	−0.16	− 903	−0.40	− 264	−0.12	− 946	−0.38	− 202	−0.08
		25	− 351	−0.23	180	0.12	− 341	−0.20	298	0.18	332	−0.18	412	0.22
		50	160	0.16	691	0.68	221	0.20	876	0.78	282	0.23	1026	0.91
	10	0	−1012	−0.52	− 588	−0.30	−1075	−0.5	− 567	−0.26	−1145	−0.49	− 552	−0.23
		25	− 523	−0.36	− 99	−0.07	− 537	−0.33	− 30	−0.02	− 557	−0.32	36	0.02
		50	34	−0.03	390	0.40	0	0	507	0.47	31	0.03	624	0.53
Cooking and lighting	5	0	2069	0.93	2761	1.2	2448	0.99	3278	1.33	2800	1.02	3768	1.38
		25	2268	1.57	3320	1.98	3066	1.65	3896	2.10	3483	1.70	4451	2.17
		50	3185	2.85	3878	3.47	3684	2.98	4514	3.65	4166	3.05	5134	3.76
	7.5	0	1162	0.54	1693	0.79	1416	0.60	2055	0.87	1669	0.65	2413	0.93
		25	1698	1.06	2229	1.39	2007	1.13	2646	1.49	2315	1.20	3059	1.58
		50	2234	2.08	2765	2.58	2598	2.20	3237	2.74	2961	2.29	3705	2.87
	10	0	591	0.29	1015	0.50	762	0.34	1270	0.56	926	0.38	1519	0.62
		25	1103	0.72	1527	0.99	1326	0.78	1834	1.08	1543	0.83	2136	1.15
		50	1615	1.58	2039	1.99	1890	1.68	2398	2.13	2160	1.75	2753	2.23
Cooking and refrigeration	5	0	229	0.11	916	0.43	338	0.14	1168	0.49	425	0.16	1393	0.53
		25	768	0.48	1455	0.90	934	0.52	1764	0.99	1083	0.55	2051	1.04
		50	1346	1.25	1993	1.92	1530	1.28	2360	1.98	1742	1.32	2710	2.06
	7.5	0	− 242	−0.11	289	0.14	− 75	−0.03	707	0.31	− 144	−0.06	601	0.24
		25	366	0.24	1171	0.75	378	0.22	1277	0.75	479	0.26	1224	0.65
		50	793	0.76	1324	1.29	951	0.83	1850	1.62	1103	0.88	1848	1.48
	10	0	− 494	−0.25	− 70	−0.04	− 51	−0.24	− 6	−0.003	− 512	−0.21	81	0.03
		25	− 5	−0.003	419	0.29	32	−0.02	540	0.33	85	0.05	678	0.38
		50	483	0.49	907	0.93	577	0.53	1085	0.99	683	0.57	1276	1.07
Cooking, lighting, and refrigeration	5	0	2915	1.30	3606	1.61	3412	1.38	4242	1.71	3861	1.41	4828	1.77
		25	3474	2.07	4165	2.49	4031	2.17	4861	2.62	4544	2.22	5511	2.69
		50	4032	3.61	4723	4.22	4650	3.76	5480	4.43	5228	3.82	6195	4.51
	7.5	0	1811	0.84	2343	1.09	2160	0.91	2799	1.18	2483	0.96	3228	1.25
		25	2347	1.46	2879	1.79	2750	1.55	3389	1.91	3129	1.62	3874	2.0
		50	2882	2.69	3414	3.18	3340	2.83	3979	3.37	3773	3.06	4518	3.50
	10	0	1109	0.54	1548	0.76	1356	0.60	1864	0.83	1576	0.64	2169	0.88
		25	1621	1.05	2045	1.33	1920	1.14	2428	1.44	2193	1.18	2786	1.51
		50	2134	2.08	2558	2.50	2483	2.20	2991	2.65	2811	2.28	3404	2.76

[a] $B/C = NPV/\bar{C}$ = Net present value/Discounted capital costs.

Table 5. Capital costs of a 5 m³ digester (30 year life) at different discount rates, subsidy rates, and foreign exchange shadow price factors with different end uses.

End use	Discount rate (%)	Subsidy rates (%)	Foreign exchange shadow price factors ($) 1.0	1.2	1.4
Cooking only		0	2038	2263	2478
	5	25	1529	1697	1859
		50	1019	1132	1239
		0	1928	2126	2326
	7.5	25	1446	1595	1745
		50	964	1013	1163
		0	1815	2003	2193
	10	25	1361	1502	1645
		50	908	1002	1097
Cooking and lighting		0	2194	2387	2614
	5	25	1646	1790	1961
		50	1047	1199	1307
		0	2030	2240	2451
	7.5	25	1523	1680	1838
		50	1015	1120	1226
		0	1909	2108	2309
	10	25	1432	1581	1732
		50	955	1054	1155
Cooking and refrigeration		0	2070	2296	2514
	5	25	1553	1722	1886
		50	1035	1148	1257
		0	1956	2158	2362
	7.5	25	1467	1511	1772
		50	978	1080	1181
		0	1845	2036	2229
	10	25	1384	1527	1672
		50	923	1018	1115
Cooking and lighting		0	2095	2327	2547
	5	25	1571	1745	1910
		50	1048	1164	1274
		0	1982	2187	2391
	7.5	25	1487	1640	1793
		50	991	1094	1196
		0	1866	2061	2255
	10	25	1400	1512	1691
		50	933	1031	1128

Table 6. Annual benefits of a 5 m³ digester. Costs in 1977 values at different foreign exchange shadow price factors with different end uses.

End use	Foreign exchange shadow price factors ($) 1.0	1.2	1.4
Cooking only	100	114	128
Cooking and six lights	280	320	360
Cooking and refrigeration	155	177	199
Cooking, two lights, and refrigeration	215	246	274
Annual fertilizer benefits	30	36	42

Table 7. Net present value (NPV) and benefit/cost (B/C) ratio of a 5 m³ digester.

			Foreign exchange shadow price factors											
			1.0				1.2				1.4			
			Fuel		Fuel and fertilizer		Fuel		Fuel and fertilizer		Fuel		Fuel and fertilizer	
End use	Discount rate (%)	Subsidy rate (%)	NPV ($)	B/C	NPV ($)	B/C	NPV ($)	B/C	NPV ($)	B/C	NPV ($)	B/C	NPV ($)	B/C
Cooking only		0	-500	-0.25	-40	-0.04	-511	-0.23	43	0.02	-510	-0.21	136	0.05
	5	25	9	0.008	469	0.3	55	0.03	607	0.36	109	0.06	755	0.41
		50	518	0.51	1002	0.98	621	0.55	1175	1.04	728	0.59	1374	1.15
		0	-747	-0.39	-393	0.20	-780	0.37	-354	0.2	-814	0.35	-316	-0.14
	7.5	25	-265	-0.18	89	0.06	-249	-0.16	177	0.11	-233	-0.13	263	0.15
		50	217	0.23	571	0.59	282	0.28	708	0.70	348	0.30	844	0.73
		0	-872	-0.48	-590	0.32	-928	-0.46	-590	-0.29	-986	-0.45	-591	-0.32
	10	25	-418	-0.31	-136	-0.10	-427	-0.28	-89	-0.46	-438	-0.27	65	0.04
		50	64	0.07	318	0.35	74	0.07	412	0.41	110	0.10	505	0.46
Cooking and lighting		0	2110	0.96	2571	1.17	2532	1.06	3085	1.29	2920	1.12	3566	1.29
	5	25	2658	1.62	3119	1.89	3129	1.75	3682	2.05	3573	1.82	4219	2.15
		50	3206	3.06	3667	3.50	3726	3.11	4279	3.59	4226	3.23	4842	3.70
		0	1277	0.63	1631	0.80	1539	0.69	1965	0.88	1801	0.73	2297	0.88
	7.5	25	1784	1.17	2138	1.40	2099	1.25	2525	1.50	2414	1.31	2910	1.58
		50	2291	2.26	2645	2.61	2659	2.37	3070	2.74	3027	2.47	3523	2.87
		0	731	0.38	1013	0.53	909	0.43	1247	0.59	1085	0.47	1480	0.59
	10	25	1208	0.84	1490	1.04	1436	0.91	1774	1.12	1612	0.93	2057	1.19
		50	1687	1.77	1967	2.06	1963	1.86	2301	2.18	2139	1.85	2634	2.28
Cooking and refrigeration		0	270	0.13	731	0.35	425	0.19	978	0.43	545	0.22	1191	0.47
	5	25	1042	0.67	1503	0.97	1270	0.74	1823	1.06	1471	0.78	2117	1.12
		50	1814	1.75	2275	2.20	2115	1.84	2668	2.32	2397	1.91	3043	2.42
		0	-127	-0.06	227	0.12	-69	-0.03	357	0.17	-13	-0.01	484	0.20
	7.5	25	580	0.40	934	0.64	712	0.47	1138	0.75	843	0.481	1340	0.76
		50	1287	1.31	1641	1.68	1493	1.38	1919	1.78	1699	1.44	2196	1.86
		0	-384	-0.20	-101	-0.05	-367	-0.18	-29	-0.01	-353	-0.16	43	0.22
	10	25	271	0.20	554	0.40	357	0.23	695	0.46	441	0.26	837	0.50
		50	926	1.00	1209	1.31	1081	1.06	1419	1.39	1235	1.12	1631	1.46
Cooking, lighting, and refrigeration		0	1210	0.37	1671	0.44	1455	0.38	2008	0.46	1665	0.39	2311	0.48
	5	25	1733	0.52	2195	0.58	2037	0.54	2590	0.60	2302	0.55	2948	0.61
		50	2257	0.68	2718	0.72	2617	0.69	3171	0.73	2038	0.70	3584	0.74
		0	557	0.22	911	0.32	718	0.15	1143	0.39	845	0.26	1341	0.36
	7.5	25	1052	0.41	1406	0.49	1265	0.44	1690	0.51	1443	0.45	1939	0.52
		50	1548	0.61	1902	0.66	1811	0.62	2236	0.67	2040	0.63	2536	0.68
		0	161	0.08	444	0.19	258	0.11	597	0.22	328	0.13	724	0.24
	10	25	627	0.31	910	0.39	807	0.35	1146	0.43	892	0.35	1288	0.43
		50	1094	0.54	1377	0.60	1288	0.56	1627	0.61	1455	0.56	1851	0.62

Table 8. Annual benefits and capital costs of a 1.5 m^3 digester (30 year life) at different discount rates, subsidy rates, and foreign exchange shadow price factors with different end uses.

			Foreign exchange shadow price factors ($)		
End use	Discount rates (%)	Subsidy rates (%)	1.0 ($)	1.2 ($)	1.4 ($)
Cooking only		0	1263	1413	1556
	5	25	947	1060	1167
		50	632	707	778
		0	1181	1310	1442
	7.5	25	886	983	1082
		50	591	655	721
		0	1098	1218	1343
	10	25	824	914	1007
		50	549	609	672
Cooking and lighting		0	1305	1460	1607
	5	25	979	1095	1205
		50	653	730	804
		0	1220	1354	1489
	7.5	25	915	1016	1117
		50	610	677	745
		0	1134	1259	1387
	10	25	851	944	1040
		50	567	630	694
Annual benefits					
Cooking only			100	114	128
Cooking and two lights			160	186	212
Fertilizer benefit			9	11	13

Table 9. Net present value (NPV) and benefit/cost (B/C) ratio of a 1.5 m^3 digester.

			Foreign exchange shadow price factors											
			1.0				1.2				1.4			
			Fuel		Fuel and fertilizer		Fuel		Fuel and fertilizer		Fuel		Fuel and fertilizer	
End use	Discount rate (%)	Subsidy rate (%)	NPV ($)	B/C	NPV ($)	B/C	NPV ($)	B/C	NPV ($)	B/C	NPV ($)	B/C	NPV ($)	B/C
Cooking only		0	274	0.22	413	0.33	339	0.24	506	0.36	412	0.26	606	0.39
	5	25	590	0.62	729	0.77	692	0.65	859	0.81	793	0.68	995	0.85
		50	906	1.44	1045	1.65	1045	1.48	1212	1.71	1174	1.51	1384	1.78
		0	0	0	106	0.09	36	0.03	165	0.13	70	0.05	219	0.15
	7.5	25	295	0.33	401	0.45	363	0.37	492	0.50	430	0.40	579	0.54
		50	590	0.99	696	1.18	690	1.05	819	1.25	790	1.10	939	1.30
		0	−155	−0.14	−70	−0.06	−143	−0.12	−41	−0.03	−136	0.10	−17	−0.01
	10	25	119	0.14	204	0.25	184	0.20	263	0.29	200	0.20	319	0.32
		50	383	0.72	478	0.87	511	0.84	567	0.93	536	0.80	655	0.97
Cooking and lighting		0	1155	0.89	1293	0.99	1399	0.96	1566	1.07	1651	1.03	1846	1.15
	5	25	1481	1.51	1619	1.65	1764	1.61	1931	1.76	2053	1.70	2248	2.23
		50	1807	2.77	1945	2.98	2129	2.92	2276	3.12	2455	3.05	2650	3.30
		0	670	0.55	776	0.64	843	0.62	971	0.72	1015	0.68	1164	0.78
	7.5	25	975	1.07	1081	1.11	1181	1.16	1309	1.29	1387	1.24	1536	1.38
		50	1280	2.10	1386	2.27	1519	2.24	1647	2.43	1759	2.36	1908	2.37
		0	374	0.33	459	0.40	494	0.39	596	0.47	612	0.44	730	0.53
	10	25	657	0.77	742	0.87	809	0.86	911	0.97	959	0.92	1077	1.04
		50	940	1.66	1025	1.81	1124	1.78	1226	1.95	1306	1.88	1424	2.05
Refrigeration	Not possible													

Table 10. Annual benefits and capital costs of a 15 m^3 neoprene bag digester (10 year life) at different subsidy rates and foreign exchange shadow price factors with different end uses.

End use	Subsidy rates (%)	Foreign exchange shadow price factors ($)		
		1.0	1.2	1.4
Cooking only	0	958	1057	1157
	25	719	793	868
	50	479	529	579
Cooking and lighting	0	1030	1137	1245
	25	773	853	934
	50	515	569	623
Cooking and refrigeration	0	988	1090	1193
	25	741	818	895
	50	494	545	597
Cooking, lighting, and refrigeration	0	1030	1137	1245
	25	773	853	934
	50	515	569	623
Annual benefits				
Cooking only		100	114	128
Cooking and six lights		280	320	360
Cooking and refrigeration		155	177	199
Cooking, lighting, and refrigeration		335	383	429
Fertilizer benefits		61	73	85

Table 11. Net present value (NPV) and benefit/cost (B/C) ratio of a 15 m^3 neoprene bag digester.

			Foreign exchange shadow price factors											
			1.0				1.2				1.4			
			Fuel		Fuel and fertilizer		Fuel		Fuel and fertilizer		Fuel		Fuel and fertilizer	
End use	Discount rate (%)	Subsidy rate (%%)	NPV ($)	B/C	NPV ($)	B/C	NPV ($)	B/C	NPV ($)	B/C	NPV ($)	B/C	NPV ($)	B/C
Cooking only		0	−186	−0.19	56	0.05	−167	−0.16	120	0.11	−169	−0.15	259	0.22
	5	25	53	0.07	295	0.41	95	0.12	382	0.48	120	0.14	548	0.63
		50	293	0.61	534	1.12	357	0.68	644	1.22	409	0.71	837	1.45
		0	−271	−0.28	−1	−0.00	−264	−0.25	58	0.06	−278	−0.24	168	0.14
	7.5	25	−14	−0.02	256	0.36	20	0.03	342	0.43	+33	+0.04	479	0.55
		50	243	0.51	513	1.1	304	0.58	626	1.13	344	0.59	790	1.36
		0	−343	−0.4	−76	−0.08	−347	−0.33	−15	−0.01	−370	−0.31	71	0.06
	10	25	−104	−0.1	163	0.23	−85	−0.11	247	0.31	−81	−0.09	360	0.42
		50	135	0.3	402	0.84	117	0.34	509	0.96	208	0.36	649	1.12
Cooking and lighting		0	1132	1.10	1373	1.33	1334	1.17	1623	1.42	1535	1.23	1963	1.72
	5	25	1388	1.80	1630	2.11	1618	1.90	1907	2.23	1846	1.98	2274	2.43
		50	1646	3.20	1887	3.66	1902	3.34	2191	3.85	2157	3.46	2585	4.15
		0	892	0.87	1163	1.13	1059	0.93	1382	1.22	1226	0.98	1673	1.35
	7.5	25	1149	1.50	1420	1.83	1343	1.57	1660	1.95	1537	1.65	1984	2.12
		50	1406	2.73	1677	3.26	1627	2.86	1950	3.31	1848	2.97	2295	4.03
		0	690	0.67	958	1.21	829	0.73	1160	1.32	967	0.78	1408	1.24
	10	25	947	1.23	1215	1.95	1113	1.30	1444	2.09	1278	1.37	1719	2.01
		50	1204	2.34	1472	2.6	1397	2.46	1728	3.63	1589	2.55	2030	3.57
Cooking and refrigeration		0	1395	1.41	2332	2.36	1630	1.50	2753	2.52	1866	1.56	3173	2.66
	5	25	1641	2.21	2579	3.48	1903	2.33	3025	4.00	2164	2.42	3471	2.88
		50	1889	3.82	2826	5.72	2176	3.99	3298	6.05	2462	4.12	3769	6.31
		0	843	0.85	1563	1.58	1000	0.92	1863	1.71	1157	0.97	2161	1.81
	7.5	25	1090	1.47	1810	2.44	1272	1.56	2135	2.61	1455	1.63	2459	2.75
		50	1337	2.71	2057	4.16	1545	2.84	2408	4.42	1753	2.94	2757	4.62
		0	473	0.48	1048	1.06	579	0.53	1267	1.16	683	0.57	1475	1.24
	10	25	720	0.97	1295	1.75	851	1.04	1539	1.88	981	1.10	1773	1.98
		50	967	1.96	1542	3.12	1124	2.06	1811	3.32	1279	2.14	2071	3.47
Cooking, lighting, and refrigeration		0	4120	4.0	5057	4.91	4750	4.18	5873	5.17	5350	4.30	6656	5.35
	5	25	4377	5.66	5314	6.87	5034	5.90	6157	7.22	5661	6.06	6967	7.46
		50	4635	9.00	5572	10.80	5318	9.35	6441	11.32	5972	9.59	7278	11.68
		0	2926	2.84	3647	3.54	3386	2.98	4248	3.74	3821	3.07	4825	3.88
	7.5	25	3183	4.12	3904	5.05	3670	4.30	4532	5.31	4213	4.94	5136	5.50
		50	3441	6.68	4162	8.08	3954	6.95	4816	8.46	4443	7.13	5447	8.74
		0	2128	2.07	2703	2.62	2474	2.18	3162	2.78	2799	2.25	3600	2.89
	10	25	2385	3.09	2960	3.83	2758	3.23	3446	4.04	3110	3.33	3911	4.19
		50	2643	5.13	3218	6.25	3042	5.35	3730	6.55	3421	5.49	4222	6.78

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